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第九巻第二號

BULLETIN

OF THE

IMPERIAL
EARTHQUAKE INVESTIGATION
COMMITTEE.

Vol. IX. No. 2.

F. Omori. The Usu-san Eruption and Earthquake and Elevation Phenomena. III.

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THE USU-SAN ERUPTION AND THE EARTHQUAKE AND ELEVATION PHENOMENA.

III.

Results of Precise Levelings in 1905-1919, with Accounts of the Observations relating to the Level Change of the Lake of Toya.

By

F. Omori, Sc.D.,
Member of the Imperial Earthquake Investigation Committee.

With Plates X–XVII.

1. Introduction. The Usu-san, which stands on the north-eastern coast of the Volcano Bay (in Hokkaido) and separates it from the lake of Toya, is a small mountain, only 736 m.* in height, whose base covers about 35 sq. km. The volcano is, however, active in eruptive manifestations, and seems to have experienced upheavals on some of the former outbursts; the formation of the principal dome, the O-Usu, evidently of no very old date, being ascribed by some authorities to the eruption in 1853. The principal phenomenon in the Usu-san eruption of 1910 consisted in the elevation of the region about the volcano, culminating in the formation of the New Mountain at the northern base bordering the lake of Toya. Even at the coast of the Volcano Bay, on the opposite side, the elevation reached nearly 1 foot. (See the Bulletin, Vol. V, Nos. 1 and 2.) It was desirous to ascertain the

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[*] Height of the O-Usu dome, according to the new Geological Survey map.

Table I. Height of the Bench Marks in 1905, 1911–13, and 1919.

In the survey of 1912, 1913, and 1919, the B.M. No. 7191 is taken as the fixed point.
„ 1911, „ No. 7190 „ „

Bench Mark.			Height.				
Locality.		No.	1905	1911	1912	1913	1919
[Abuta Village District.]			m.	m.	m.	m.	m.
ビハオク	Abuta, Biwaok.	6596	49.0857	50.2574	50.2340	50.2259	50.2057
床丹	„ Tokotan.	6597	150.6192	150.5629	150.5241	150.5273	150.5255
	„ „	6598	93.0124	95.4542	95.4125	95.4111	95.3932
プオシマ	„ Puoshima.	6599	86.3755	86.3569	86.3403	86.3519	86.3540
ポロモイ	„ Poromoi.	6600	88.6877	88.6891	88.6675	88.6843	88.6848
„	„ „	6601	86.1620	86.1658	86.1393	86.1568	86.1558
オオザク	„ Oozak.	6602	86.8139	86.8168	—	—	86.8103
向洞爺	Muko-Toya.	6603	86.2596	86.2663	—	—	86.2597
„	„	6604	—	—	—	—	85.5009
チヤスナイ	Abuta, Chasnai.	7190	140.6111	104.6111	—	—	—
クリヤ	„ Kriya.	7191	60.2509	60.2465	60.2509	60.2509	60.2509
フレナイ	„ Frenai.	7192	2.6572	2.6346	2.6372	2.6337	2.6299
床丹	„ Tokotan.	VI	3.5676	3.9296	3.9248	3.9169	3.9027
オモナイ	„ Omonai.	7193	9.5764	—	9.7852	9.7804	9.7671
[Daté Village District.]							
有珠	Usu, Sneushima.	7194	3.7524	—	3.9553	3.9462	3.9282
„	„	7195	30.0242	—	30.1671	30.1651	30.1495
長流, オサルベツ	Osarubets.	7196	6.4822	—	6.5629	6.5641	6.5458
西紋鼈タラヤマ	Tarayama.	7197	4.2696	—	4.2857	4.2927	4.2710
„ 裏濱	Urahama.	7198	—	5.5162	5.5217	5.5270	5.5040
シヤシチセ	Hi. Moubets,	7199	14.0073	—	—	14.0194	14.0026
ハギハラ	„	7200	14.1432	—	—	14.1556	14.1371
マレツプ	Marep.	7201	11.9577	—	—	—	11.9483
オコンポニベ	Okonbonibe.	7202	2.8598	—	—	—	2.8539
„	„	7203	2.3877	—	—	—	2.3827

TABLE II. Height Variations of the Bench Marks, between the years 1905 and 1919.

(Referred to the B.M. No. 7191 as fixed point.)

Bench Mark.	Height Variation.					
No.	1905 to 1911	1905 to 1912	1912 to 1913	1913 to 1919	1905 to 1919	1911–12 to 1919
Abuta Village District.	m.	m.	m.	m.	m.	m.
6596	+ 1.1717	+ 1.1483	− 0.0081	− 0.0202	+ 1.1200	− 0.0422
6597	− 0.0563	− 0.0951	+ 0.0032	− 0.0018	− 0.0937	− 0.0202
6598	+ 2.4418	+ 2.4001	− 0.0014	− 0.0179	+ 2.3808	− 0.0424
6599	− 0.0186	− 0.0352	+ 0.0116	+ 0.0021	− 0.0215	+ 0.0032
6600	+ 0.0014	− 0.0202	+ 0.0168	+ 0.0005	− 0.0029	+ 0.0043
6601	+ 0.0038	− 0.0237	+ 0.0175	− 0.0010	− 0.0062	+ 0.0010
6602	+ 0.0029	—	—	—	− 0.0036	—
6603	+ 0.0067	—	—	—	+ 0.0001	—
6604	—	—	—	—	—	—
7190	0.0000	—	—	—	—	—
7191	− 0.0044	0.0000	0.0000	0.0000	0.0000	0.0000
7192	− 0.0722	− 0.0200	− 0.0035	− 0.0038	− 0.0273	− 0.0082
VI	+ 0.3620	+ 0.3572	− 0.0079	− 0.0142	+ 0.3351	− 0.0267
7193	—	+ 0.2088	− 0.0048	− 0.0133	+ 0.1907	− 0.0181
Daté Village District.						
7194	—	+ 0.2029	− 0.0091	− 0.0180	+ 0.1758	− 0.0271
7195	—	+ 0.1429	− 0.0020	− 0.0156	+ 0.1253	− 0.0176
7196	—	+ 0.0807	+ 0.0012	− 0.0183	+ 0.0636	− 0.0171
7197	—	+ 0.0161	+ 0.0070	− 0.0217	+ 0.0014	− 0.0147
7198	—	—	+ 0.0053	− 0.0230	—	− 0.0172
7199	—	—	+ 0.0121	− 0.0168	− 0.0047	− 0.0037
7200	—	—	—	− 0.0185	− 0.0061	—
7201	—	—	—	—	− 0.0094	—
7202	—	—	—	—	− 0.0059	—
7203	—	—	—	—	− 0.0050	—

course of the height variation subsequent to the eruption in question, and through the liberality of the Imperial Academy and the good will of the Military Survey, the necessary leveling work has been carried on in June-Aug., 1919, a new height examination having been made of the 23 bench marks over the distance of 44 km. along the coast of the Volcano Bay and across to the west coast of the lake of Toya. Previous to 1919, the height re-examination had been executed partially along the lines of precise leveling under consideration during the three successive years 1911 to 1913. The results of the different surveys are given in Tables I and II.

2. Height difference between 1905 and 1919. Of the different bench marks taken in our consideration those furthest from the centre of the Usu-san, on whose northern slope the New Nountain is situated, are Nos. 6604, 7191 (or 9190), and 7203, as follows:—

B.M. No.	6604,	.........$9\frac{1}{2}$ km. to the N.7° W., on the N.W. coast of the lake.
,,	7191,	.........$7\frac{1}{2}$ km. to the N.75°W., on the coast of the Volcano Bay.
,,	7203,	.........17 km. to the S.40°E., on the coast of the Volcano Bay.

The height difference along the leveling lines about the Usu-san between 1905 and 1919, respectively 5 and 9 years before and after the eruption, is shown in Table III, there being no material difference in the result whichever of the three above mentioned bench marks be taken as the fixed point. Moreover the amount of the change was very slight for the 5 bench marks Nos. 6600 to 6604 on the west coast of the Toya lake and for the 7 bench marks Nos. 7197 to 7203 on the coast of the Volcano Bay. Marked level change was thus limited to the Usu-san district about 5 km. in

TABLE III. Height Difference of the different Bench Marks, between the years 1905 and 1919.

Bench Mark. No.	Height Change between 1905 and 1919.		Bench Mark. No.	Height Change between 1905 and 1919.	
	B.M. No. 7203 as fixed point.	B.M. No. 7191 as fixed point.		B.M. No. 7203 as fixed point.	B.M. No. 7191 as fixed point.
	m.	m.		m.	m.
7191	+ 0.005	0.000	6596	+ 1.125	+ 1.120
7192	– 0.022	– 0.027	6597	– 0.089	– 0.094
VI	+ 0.340	+ 0.335	6598	+ 2.386	+ 2.381
7193	+ 0.196	+ 0.191	6599	– 0.017	– 0.022
7194	+ 0.181	+ 0.176	6600	+ 0.002	– 0.003
9195	+ 0.130	+ 0.125	6601	– 0.001	– 0.006
7196	+ 0.069	+ 0.064	6602	+ 0.001	– 0.004
9197	+ 0.006	+ 0.001	6603	+ 0.005	0.000
9198	—	—	6604	+ 0.008	+ 0.003
7199	0.000	– 0.005			
7200	– 0.001	– 0.006			
7201	– 0.004	– 0.009			
7202	– 0.001	– 0.006			
7203	0.000	– 0.005			

radius, bounded on the east by the Osaru river, and on the west by the line connecting the three bench marks Nos. 6599, 6597, and 7192, which nearly coincides with the shortest distance between the lake and the bay. Only the three last mentioned bench marks indicated definitely the depression of the ground, which, taking the B.M. No. 7203 at the S.E. end as the fixed point, amounted to 0.017; 0.089, and 0.022 m. respectively. On the contrary, the other bench marks at the western base and all those at the southern base of the Usu-san were considerably elevated; the amount of the change being specially marked and

Pl. X.

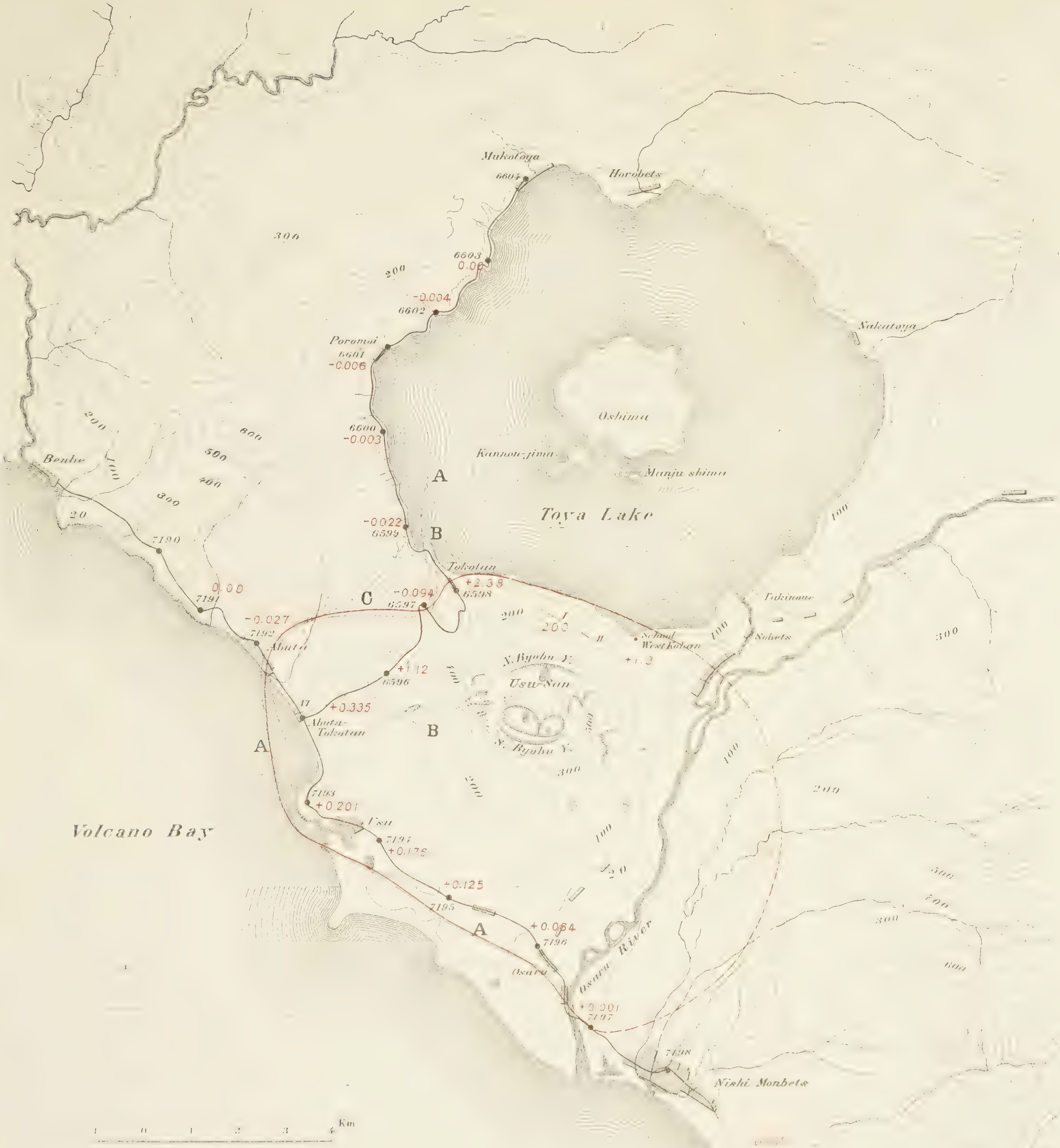

Fig. 1. Map showing the Height Difference in the Usu-san District between 1905 and 1919, respectively 5 years before and 9 years after the Eruption of 1910.

The red closed curve is the boundary of the elevated region. The red figures indicate the amount of change of the bench mark heights in 1919 relative to 1905, plus (+) when augmented and minus (–) when lessened.

Town or village.

Line of precise levelling and bench marks.

I, II are the Dislocation Lines of the "New-Mountain,"

Contour lines, which relate to the topography before the eruption, are given for heights of 20 m., 100 m., 200 m., 300 m., etc. above sea-level.

The two thin black curves A and B relate to the comparison of the bench mark heights in 1911–1912 with those in 1905, being respectively the line of no level change and the line of 1 metre elevation before and after the eruption of 1910. C is the line of no level change between 1911 and 1912.

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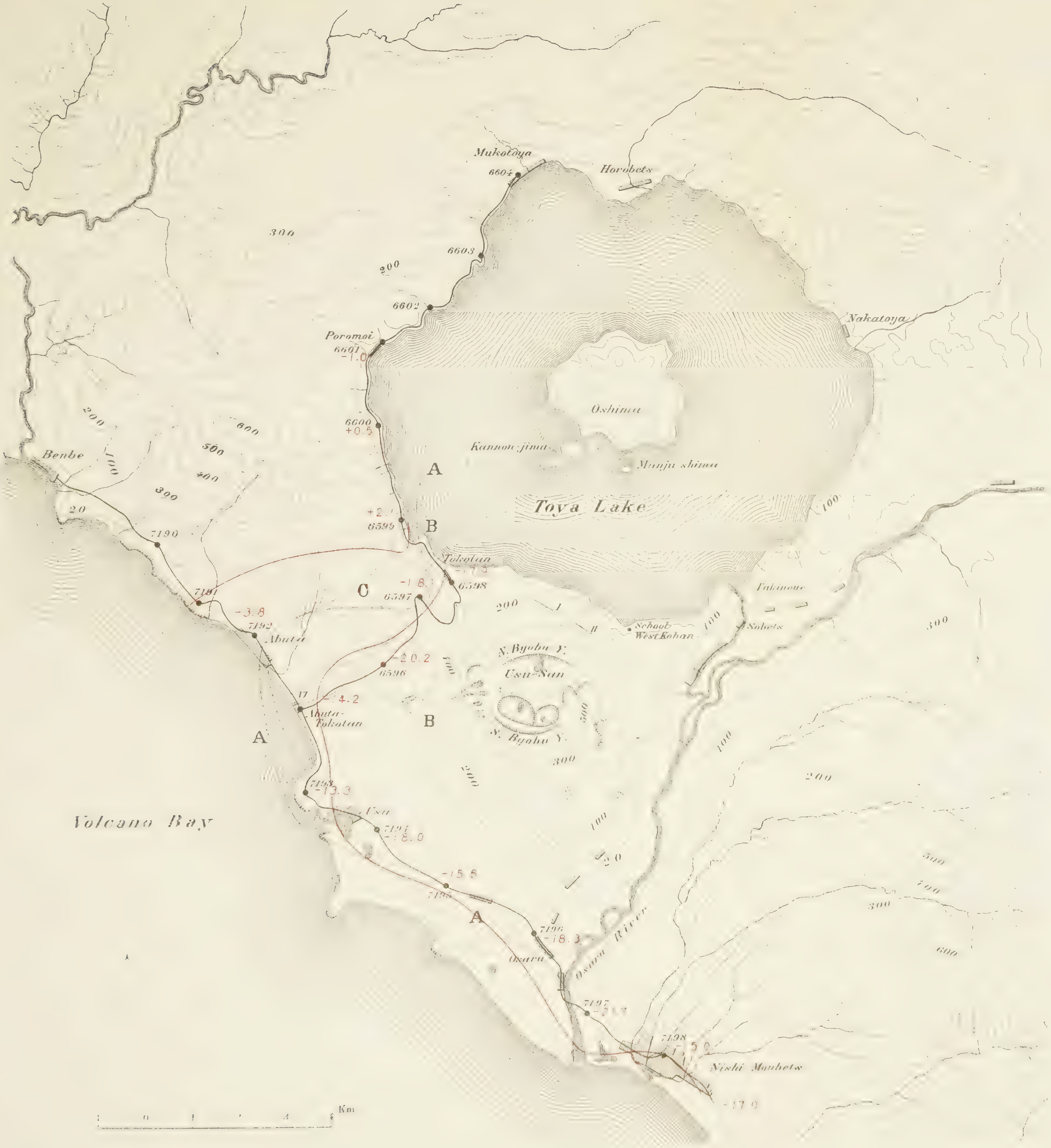

Pl. XI.

Fig. 3. Map showing the Height Difference in the Usu-san District between 1913 and 1919, respectively 3 and 9 years after the Eruption.

The outer (shorter) red curve is the line of no height change and the inner red curve is the line of 15 mm. depression of the ground in 1919 relative to 1913. The red figures indicate the change in the heights, plus (+) when augmented and minus (−) when lessened.

Town or village.

Line of precise levelling and bench marks.

I, II are the Dislocation Lines of the "New-Mountain."

Contour lines, which relate to the topography before the eruption, are given for heights of 20 m., 100 m., 200 m., 300 m., etc. above sea-level.

The two thin black curves A and B relate to the comparison of the bench mark heights in 1911–1912 with those in 1905, being respectively the line of no level change and the line of I metre elevation before and after the eruption of 1910. C is the line of no level change between 1911 and 1912.

seems to be the result of a great local upheaval, essentially with the pivot axis situated on, and parallel to the shore line, a strip of the land along the lake was depressed to the maximum width of about 35 m., the coast itself having been submerged to the maximum depth of about 12 feet.

As will be seen from fig. 1, the present condition of the change due to the eruptive activity of 1910 consists mainly in the elevation of the Usu-san region measuring about 10 km. in the N.W.–S.E. and 7½ km. in the N.E.–S.W. direction. In this area the height change was most conspicuously displayed at the northern part, culminating in the formation of the New Mountain raised about 200 m., and in the second place, at the north-western part, where the B.M. No. 6598 was elevated about 2.4 m. Thus the depression of the ground, which was only definitely shown just outside the portions of a special elevation, may be regarded as the effect of a dislocation or fault produced about the latter.

3. Course of height variation between 1905 and 1919. The difference between the ground level in 1919 and that in 1905 considered in the preceding §, which was in the main produced at and immediately after the eruption of 1910, is the result of the addition of the small subsequent height changes. The approximate course of the variation of the latter during the interval of the 14 years in question can be clearly seen, amongst the others, of the two groups of the bench marks, (A) Nos. 6598, 6596, and VI, and (B) Nos. 6597, 6599, and 7192, which in 1910 suffered significant changes of elevation and depression respectively, and which were all surveyed in the 5 years, 1905; 1911; 1912; 1913; and 1919. According to Tables IV and V, in 1912 the different bench marks alike suffered some depression, which in the case of the A group progressed on uninterruptedly. It is true that the B.M. No. 6598, which had experienced in 1910–1911 the great elevation of 2.4462 m., has also suffered the greatest depression of 0.0654 m. in the interval of the subsequent 8 years. But otherwise the total depression in 1919 relative to 1911 (*f*, in Table V) was not much dependent on the amount of the elevation or depression produced at the time of the eruption (*a*, in Table V). Thus the change on the latter occasion of the B.M. No. 6596 was an elevation of 1.1761 m. and that of the B.M. No. 6597 a depression of 0.0519 m.; and yet these two bench marks had in 1919 the total depressions respectively of 0.0561 m. and 0.0458 m., not very much different from the corresponding quantity for the B.M. No. 6598.

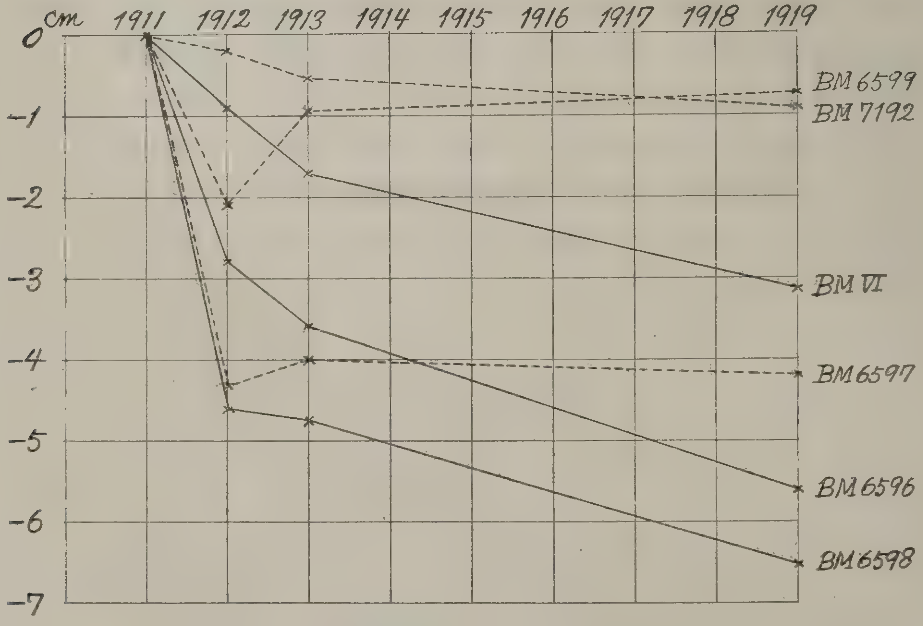

Fig. 2. Amount of the Height Change of the Different Bench Marks in 1912, and 1913, and 1919, referred to 1911.

Bench marks Nos. VI, 6596, and 6598 suffered marked elevations at the time of the Usu-san eruption (1910), while Nos. 6599, 7192, and 6597 indicated slight but distinct depressions on the same occassion.

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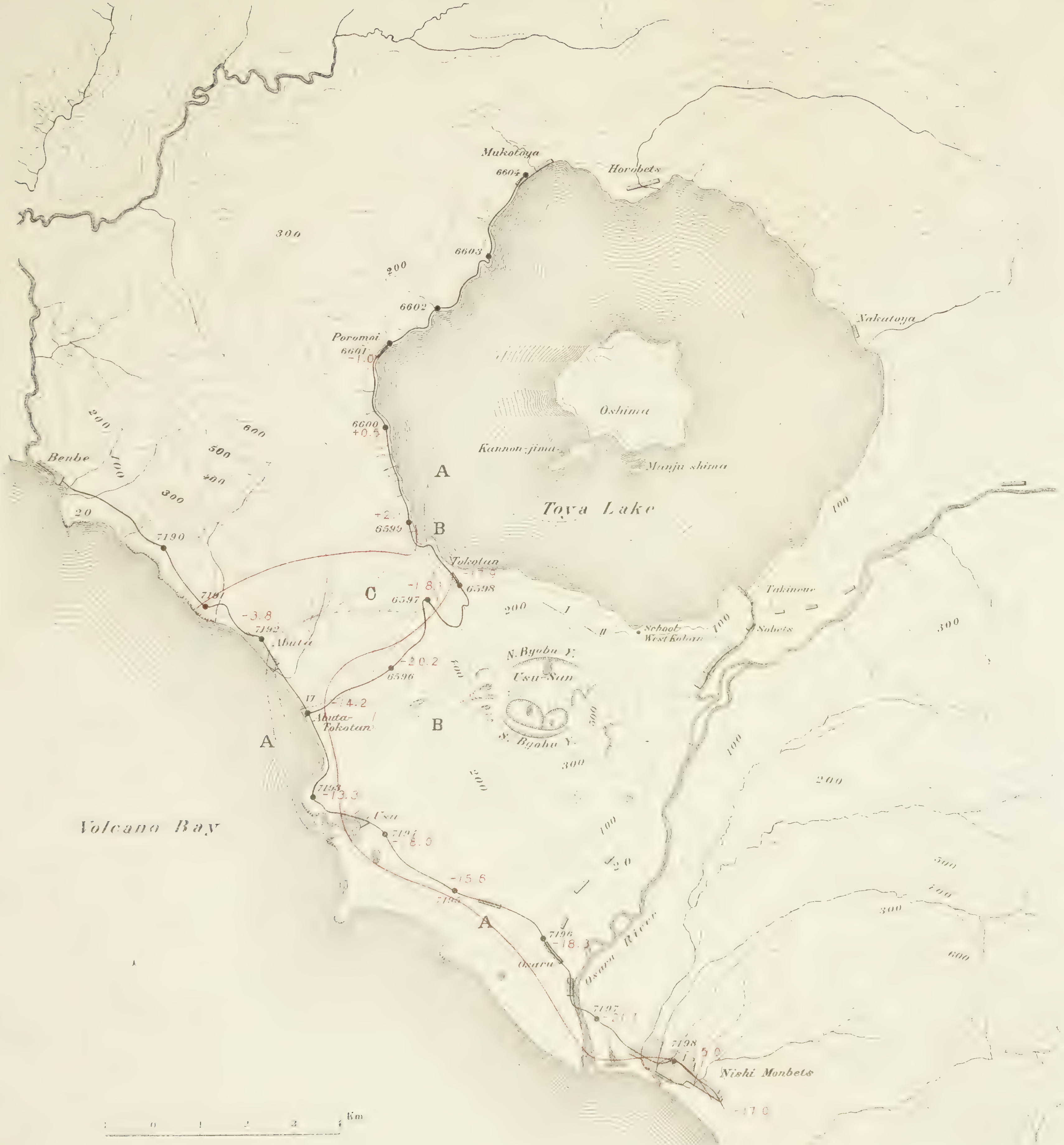


Pl. XI.

Fig. 3. Map showing the Height Difference in the Usu-san District between 1913 and 1919, respectively 3 and 9 years after the Eruption.

The outer (shorter) red curve is the line of no height change and the inner red curve is the line of 15 mm. depression of the ground in 1919 relative to 1913. The red figures indicate the change in the heights, plus (+) when augmented and minus (−) when lessened.

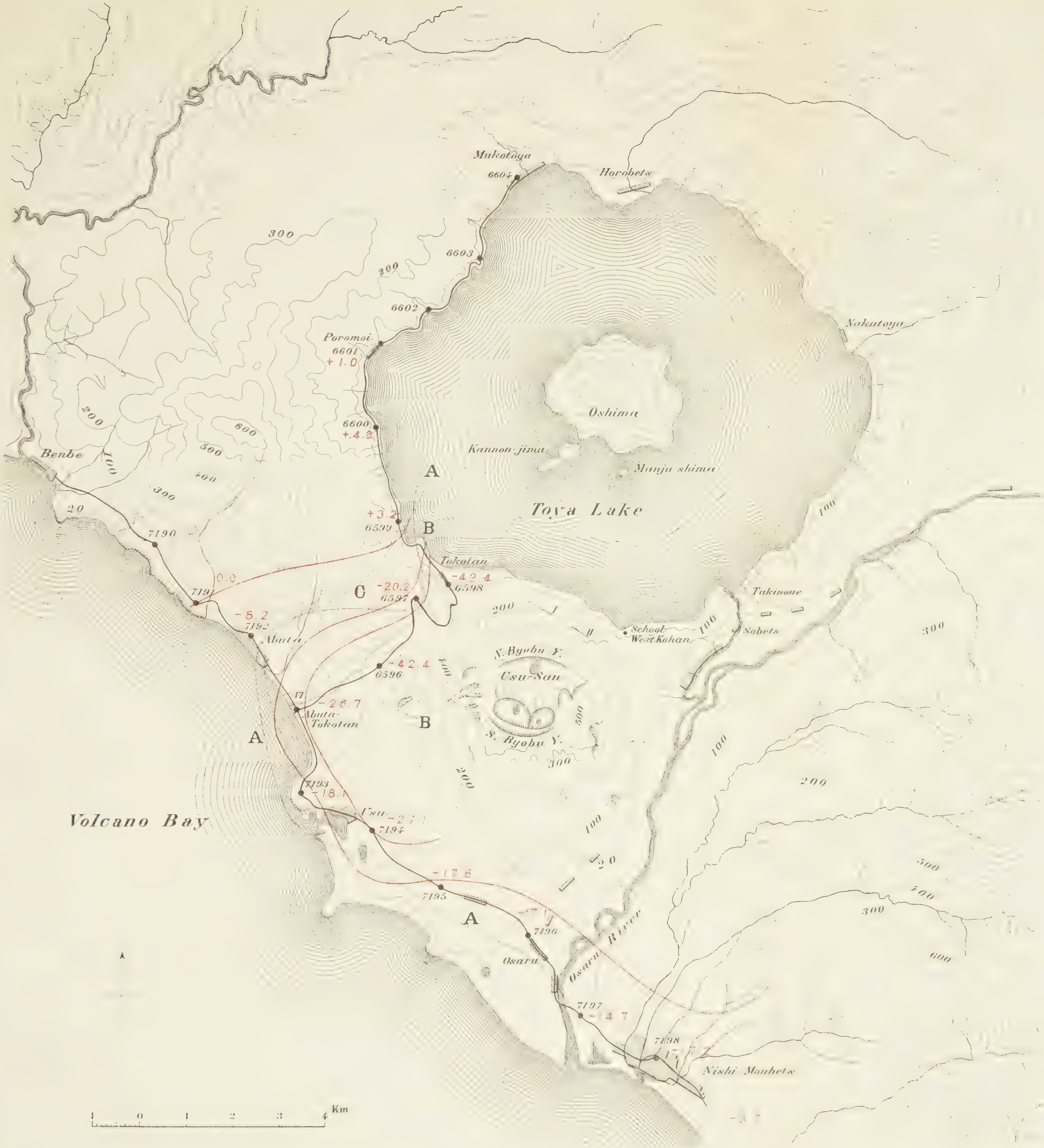
▭ Town or village.

Line of precise levelling and bench marks.

I, II are the Dislocation Lines of the "New-Mountain."

Contour lines, which relate to the topography before the eruption, are given for heights of 20 m., 100 m., 200 m., 300 m., etc. above sea-level.

The two thin black curves A and B relate to the comparison of the bench mark heights in 1911–1912 with those in 1905, being respectively the line of no level change and the line of 1 metre elevation before and after the eruption of 1910. C is the line of no level change between 1911 and 1912.



Pl. XII.

Fig. 4. Map showing the Height Difference in the Usu-san District between 1911–12 and 1919.

The outermost (short) red curve is the line of no change, and the two inner red curves are respectively the lines of 20 mm. and 27 mm. depressions of the ground in 1919 relative to the two years 1911 and 1912 taken together. The red figures indicate the changes in the height, plus (+) when augmented and minus (−) when lessened.

Town or village.

Line of precise levelling and bench marks.

I, II are the Dislocation Lines of the "New-Mountain."

Contour lines, which relate to the topography before the eruption, are given for heights of 20 m., 100 m., 200 m., 300 m., etc. above sea-level.

The two thin black curves A and B relate to the comparison of the bench mark heights in 1911–1912 with those in 1905, being respectively the line of no level change and the line of I metre elevation before and after the eruption of 1910. C is the line of no level change between 1911 and 1912.

Table VI. Height Variation of the Different Bench Marks between 1905 and 1912, and between 1913 and 1919.

Positive (+) when the height increases, and negative (−) when the height decreases.

[A] B. M.	1905—1912 (Elevation.)	1913—1919 (Depression.)	[B] B. M.	1905—1912 (Depression.)	1913—1919.
	m.	m.		m.	m.
6596	+ 1.1483	− 0.0202	7192	− 0.0200	− 0.0038
6598	+ 2.4001	− 0.0179	6599	− 0.0352	+ 0.0021
VI	+ 0.3572	− 0.0142	6600	− 0.0202	+ 0.0005
7193	+ 0.2088	− 0.0133	6601	− 0.0237	− 0.0010
7194	+ 0.2029	− 0.0180	6597	− 0.0951	− 0.0018
7195	+ 0.1429	− 0.0156			
7196	+ 0.0807	− 0.0183			
6197	+ 0.0161	− 0.0217			
7198	......	− 0.0150			
7199	0.0000	− 0.0168			
7200	......	− 0.0185			
Mean.	....	− 0.0172	Mean.	....	− 0.0008

The depression in 1912 relative to 1911, (*b*, in Table V), however, had, for the A group bench marks, a nearly constant ratio to the elevation at the time of the eruption (*a*), giving the mean value of 2.3%, as follows:—

B. M.	(a) Elevation. 1905—1911	(b) Depression. 1911—1912	Ratio : b/a
No. 6598	2.4462 m.	0.0461 m.	2.03 %
„ 6596	1.1761	0.0278	2.36
„ VI	0.3664	0.0092	2.51

Thus the amount of the restitution (depression) of the markedly disturbed localities was at first proportional to that of the original elevation. After 1913, the recovery process became very slight, and was, as illustrated in fig. 2, nearly of a constant rate for the three bench marks in question. This last fact is found to be approximately true of all the bench marks elevated on the occasion of the eruption of 1910, as explained next.

4. Height change between 1913 and 1919. Table VI gives the height changes between 1913 and 1919 and between 1905 and 1912. It will be observed that the A group bench marks, which had experienced an elevation in 1910, have all been depressed in the course of the 6 years, 1913–1919, to nearly the same amount, namely, from 0.0133 m. to 0.0217 m., with the mean value of 0.0172 m. It thus seems that the Usu-san region elevated by the eruption is, after 1913, settling down as a whole, at the average rate of 0.0172/6 m. = 3 mm. per year, irrespective of the extent of the change in 1910. On the other hand, the B group bench marks, which had undergone a depression in the latter year, indicated irregular and very slight changes in the time interval under consideration, giving on the average the depression rate of 0.13 mm. per year.

From the map (fig. 3) illustrating the results stated above, it will be seen that the depression curve of 15 mm. runs on the W. and the S. sides of the Usu-san approximately along the contour lines, the amount of the depression (height restitution) probably being greater at or near the centre of the volcano.

5. Height in 1911 and 1912 compared to that in 1919. To obtain a general idea about the level change subsequent to the eruption, let us take the B. M. No. 7191 as the fixed point, and compare the heights in 1911 and 1912 with those in 1919. The results (fig. 4) indicate a well-marked depression all about the Usu-san, which, in the interval of the 7 or 8 years concerned, reached the mean group values of 0.0423 m., 0.0269 m., and 0.0175 m., as follows:—

B. M. No.		
6596	−0.0422 m.	Mean, −0.0423 m.
6598	−0.0424	
7194	−0.0271	,, −0.0269 m.
VI	−0.0267	
7193	−0.0181	,, −0.0175 m.
7195	−0.0176	
7196	−0.0171	
7197	−0.0147	
7198	−0.0172	
6597	−0.0202	

To the S.E. and the N.W. of the area in question there was a slight height change, resulting in the mean depression of 0.0060 m. and the mean elevation of 0.0025 m.:—

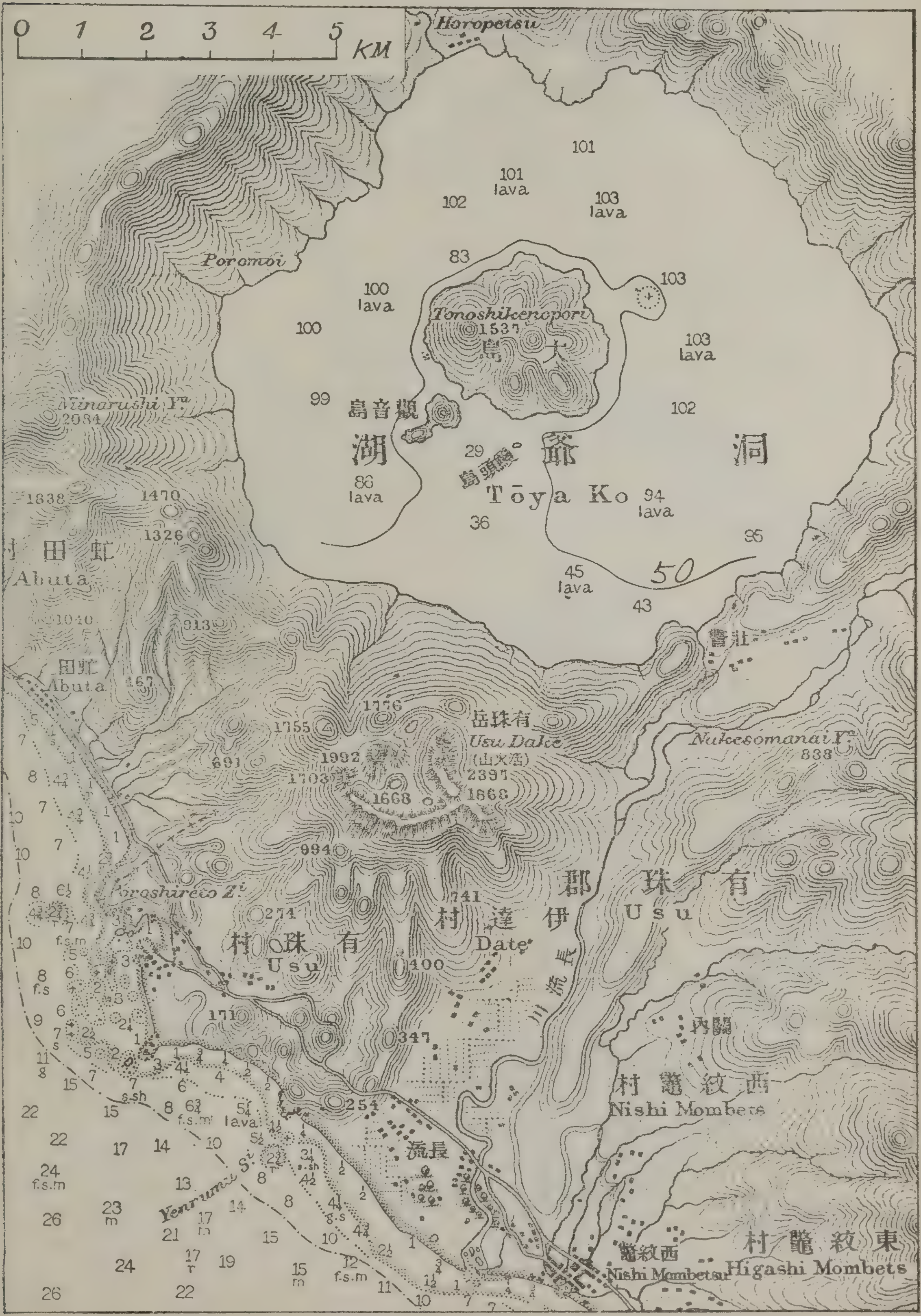
B. M. No.		
7196	−0.0082 m.	Mean, −0.0060 m.
7199	−0.0037	
6599	+0.0032	,, +0.0025 m.
6600	+0.0043	
6601	+0.0010	

6. Remark on the height variation. Subsequent to the remarkable elevation phenomena which accompanied the Usu-san eruption of 1910, the restitution process has set in, whose maximum effect was indicated at the B.M. No. 6598, the ratio of the total amount of the recovery to the original upheaval being 2.7 : 100. Since 1913, the process of the depression has become much slower, being only 3 mm. per year. Even supposing this change rate to be continued for 100 years, the resultant depression would be some 30 cm., which is far smaller than the elevation in 1910 of the B.M. Nos. 6596 and 6598. Hence the region elevated in the last eruption would not be brought back to its old level before the next volcanic disturbance, likely to occur earlier, but preserve the elevated condition essentially for ever. The restitution or level depression, which set in since 1911, extended also over the greater portion of the adjacent tract which had suffered a slight depression in 1910. The depression effect of the latter was, as may easily be imagined much smaller than the restitution change of the originally upheaved area.

7. Lake Toya and New Mountain. The lake of Toya, separated by the Usu-san from the Volcano Bay, is an irregular circle or rather a hexagon, about 11 km. in diameter, whose surface is about 85 m. above sea-level. Nearly at the centre of the lake there is situated the island of Nakano-shima (or O-shima), 441 m. in height and about 3 km. in diameter, with the appendage of the small islets of Kwannon-jima off the S.W. and a sunken rock off the N.E. coast. According to the hydrographic chart of the navy, issued in 1904, the maximum depth of the lake found to the N.E. and the E. of the Nakano-shima, was 103 fathoms=188 m. (See fig. 5.) According, however, to the soundings made by Dr. Hidezo Tanakadate in 1917, the water depth at the corresponding portion of the lake nowhere exceeded 180 m. =99 fathoms, while the maximum depth found off the N.W. coast, was 184 m. =101 fathoms. (See fig. 6.) This discrepancy is of the same order of magnitude as the depression and elevation of the bottom of the inner Kagoshima bay produced by the great Sakura-jima eruption of 1914, and may possibly be attributed to the upward volcanic tension which resulted in the formation of the New Mountain, and which might have affected also the deeper part of the lake bottom, as the latter must have been brought down to its present level by the subsidence related to the volcanic action in the immediate neighbourhood and must specially be sensitive to changes in the vertical direction.

Fig 5. Chart of the Lake of Toya (Toya Ko).

Reproduced from the Imperial Navy Hydrographic Chart No. 17, published in 1904, or 6 years before the Usu-san Eruption of 1910.

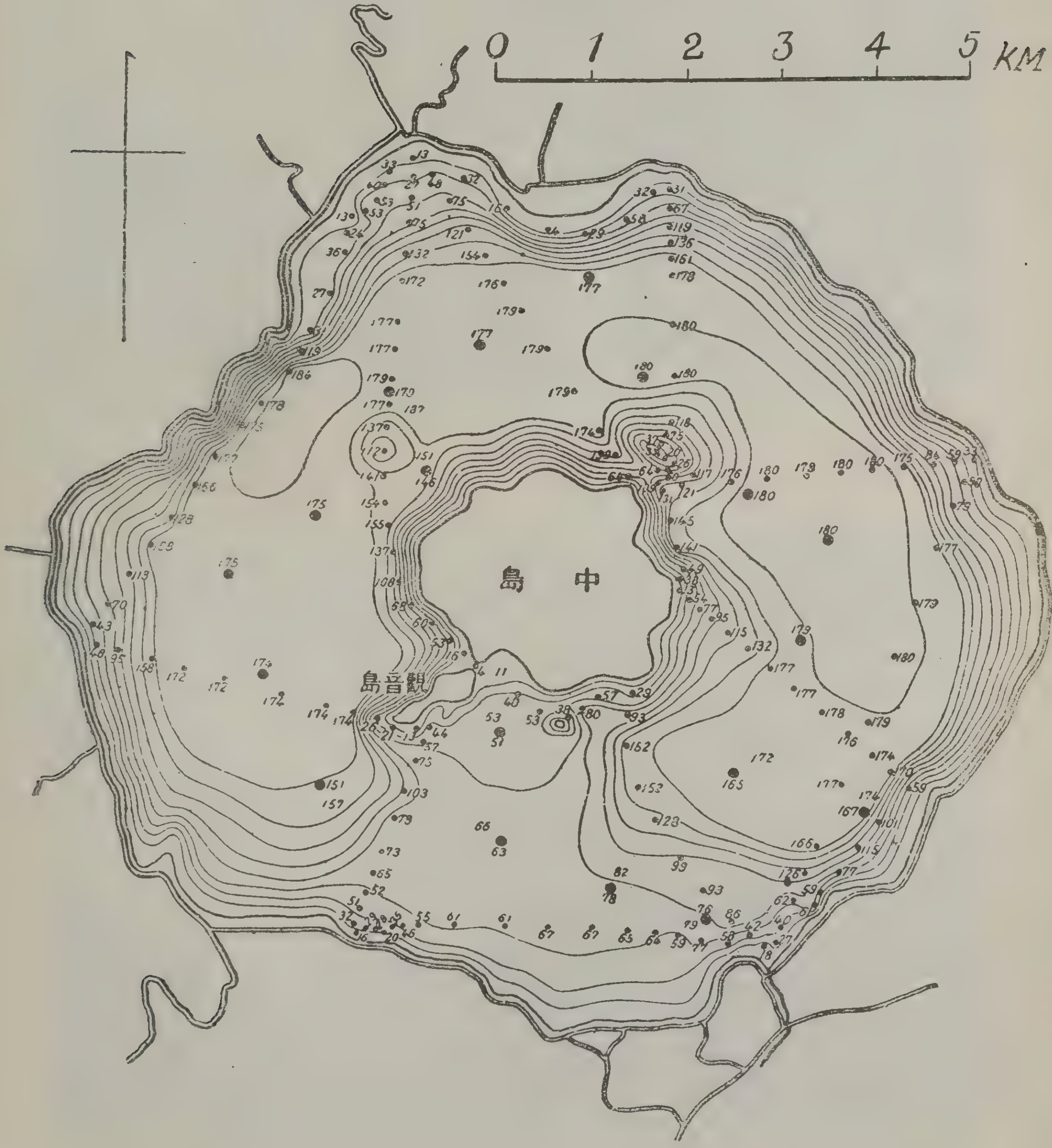


Soundings in fathoms. Height expressed in feet above H.W. Springs of the Volcano Bay.

Fig. 6. Chart of the Lake of Toya.

Compiled by Dr. Hidezo Tanakadate from his soundings made in 1917. Reproduced from the Chigak-Zasshi (Journal of Geographical Society of Tokyo), 1918.

Soundings in metres.
Isobaths are drawn for every 20 m. depth.



The Usu-san Eruption of 1910. (F. Omori, phot.)

Outburst of vapour and mud from the craterlet at the south foot of the West Maru-yama, photographed on July 31st, 1910. (×) Mud Stream. (××) West Maru-yama.

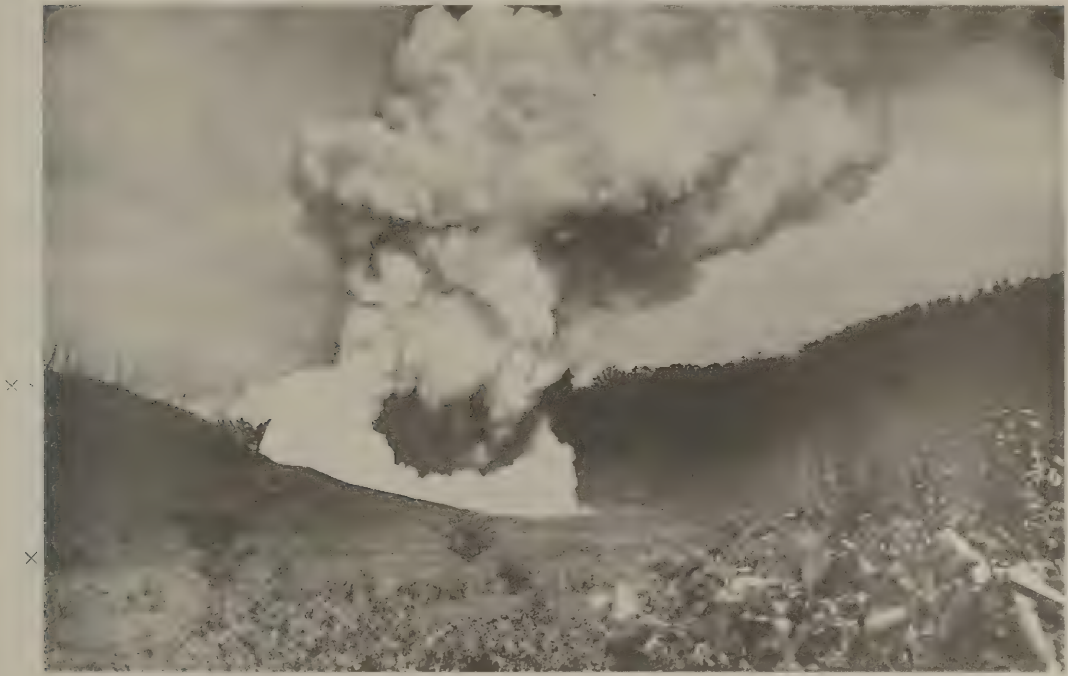


Fig. 7. Moist material spreading out in divergent pointed forms at the base of the smoke column.

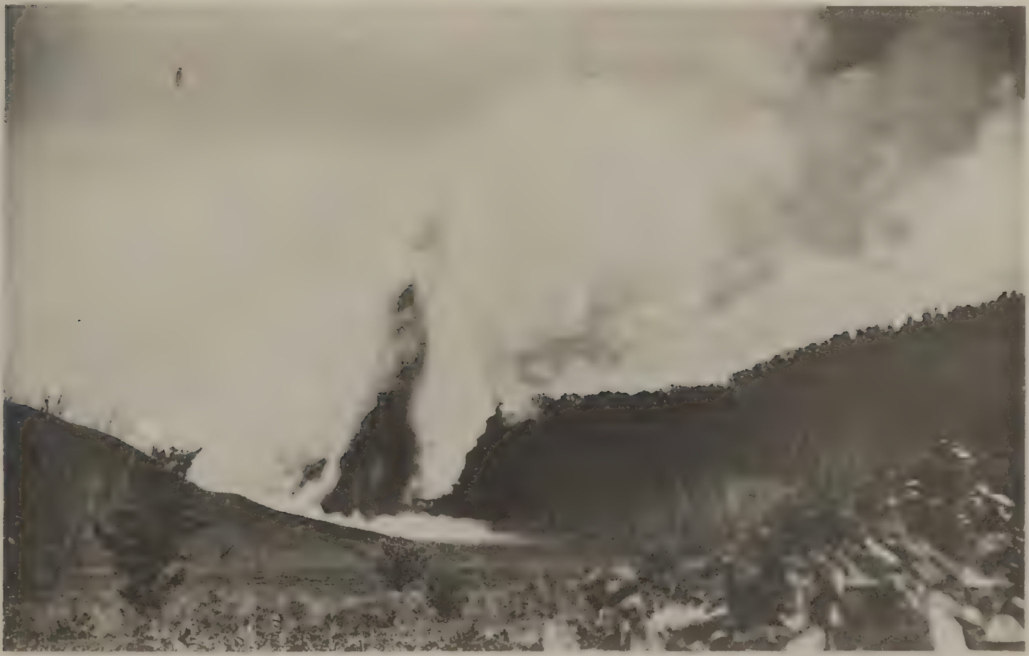


Fig. 8. Projection of moist material in a single spear-head like shape. Height of ascent = 100 m.

The Usu-san Eruption of 1910. (F. Omori, phot.)

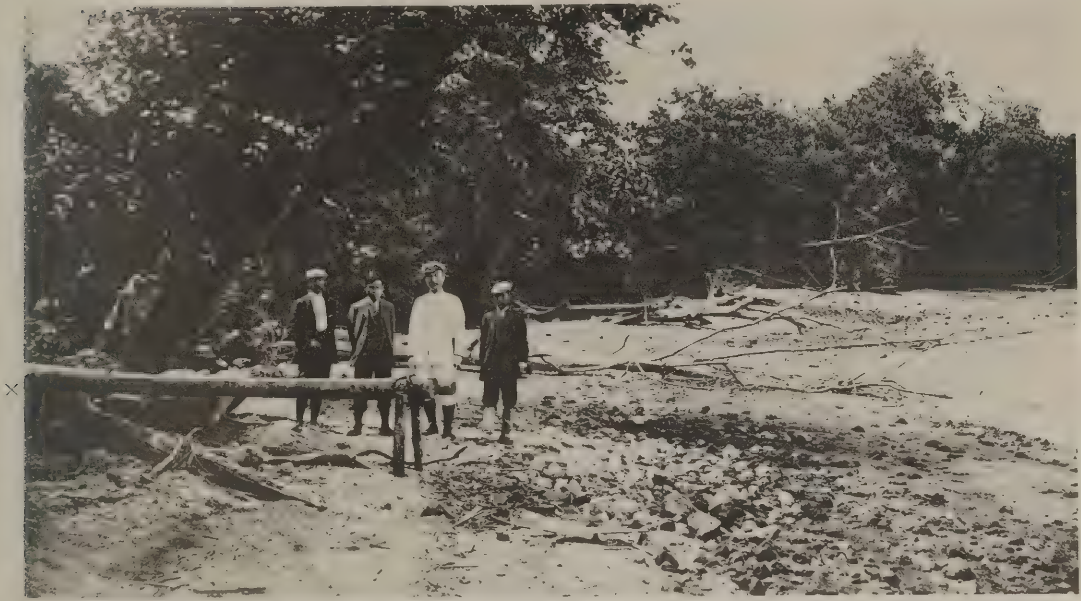


Fig. 9. Elevation of the West Kohan Lake Coast: a small wooden pier (×) standing entirely out of the water, which had receded several metres from the coast. (Aug. 3rd, 1910.)

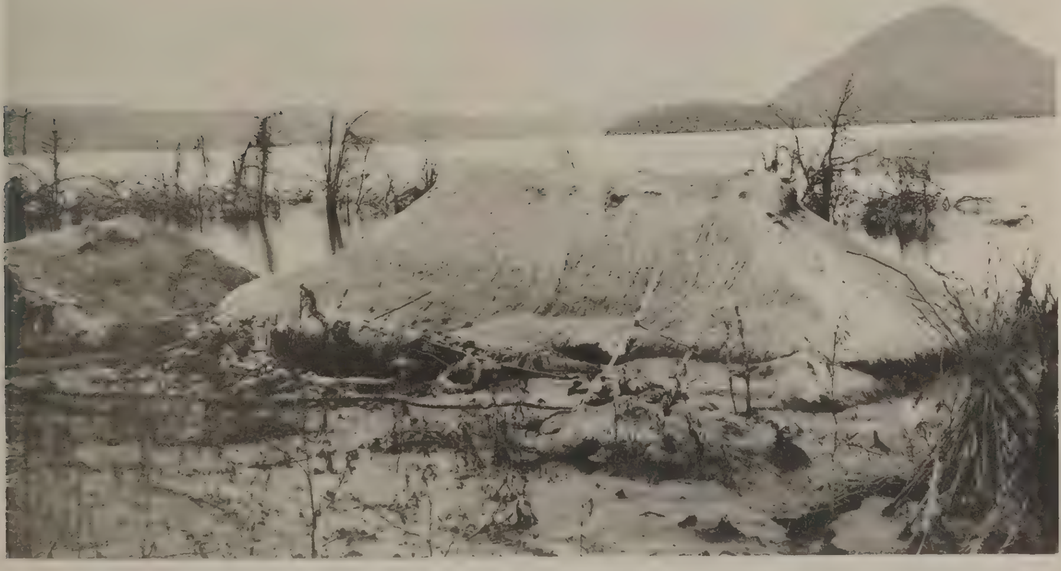


Fig. 10. A consequence of the Elevation of the new Mountain: Cottages at Pontokari overthrown on account of the increasing inclination of the ground. The submerged trees show the subsidence of the shore due to the elevation of the northern slope of the New Mountain. (Nov. 10th, 1910.)

From figs. 5 and 6 it will be seen that, except on the south, the water depth rapidly increased off the coast as well as off the Nakano-shima island, the boundary of the flat bottom of the lake 2 km. in width and about 90 fathoms or 160 m. in depth, being reached at the distance generally of 450 m. to 1 km. from either. On the south, the Nakano-shima is connected to the Usu-san by a submerged plateau or ridge, 2 km. in width and less than 50 fathoms in depth. The presence of this elevated portion surrounded on three sides by a deep depression is a feature verified more or less similarly in the case of the inner Kagoshima bay, where the shallow area surrounding the Anei (1779) islets protrudes northwards from the N.E. coast of the Sakura-jima and separates the deep basin into the western and eastern parts. (See the Bulletin, Vol. VIII, No. 4.)

It is interesting that the New Mountain of 1910 has been raised on the southern prolongation or end of the ridge between the Usu-san and the Nakano-shima, which belongs undoubtedly to the same system of elevation as these volcanoes themselves. The formation of the inner and higher side of the New Mountain by a dislocation along a line in the direction of E.E.S.–W.W.N. seems to indicate that the upheaving volcanic force was manifested along a crack or zone of the secondary nature formed at right angles to the length of the ridge in question. In this connection, it may be noted that the line joining the O-Usu (the greater Usu) and the Ko-Usu (the lesser Usu), mutually distant 850 m., is in the direction of E.E.S. and W.W.N. (See Pl. III, the Bulletin, Vol. V, No. 1.) These two Usu-san domes may, therefore, be regarded as having been formed along a crack, which belongs to the same category as the dislocation of the New Mountain and was formed normal to the volcanic line joining the centres of the Usu-san and the Toya lake. The newer and greater dome of O-Usu is also, amongst the others, diametrally cleft by a dislocation line running in the direction of N60°W.-S.60°E.

8. Elevation of the West Kohan coast of the lake. In connection with the formation of the New Mountain, the elevation of the West Kohan (or Pontokari) coast of the Toya and the increase of the lake water on the occasion of the Usu-san eruption in 1910, will be here considered in detail. (For a brief general account of the observations relating to the facts in question, the reader is referred to the Bulletin, Vol. V, No. 1.)

The elevation of the ground at West Kohan at the S.S.E. coast of the lake, first noticed on Aug. 6th (1910), extended for the length of about 1 mile and had began on, or more likely earlier than, the date of the first eruption, namely, July 25th. To observe the subsequent rate of the elevation, the height of the lake surface was measured by means of a graduated post erected in the shallow water in front of the West Kohan village school, near the east end of the affected coast and the result was compared with the readings of the level-gauges at the 4 other places situated around the lake, namely, Naka-Toya, Muko-Toya, Takinoue, and Tokotan (Kohan Tokotan). The level observation at the former two of these places was instituted temporally after the commencement of the eruption, while that at the latter two had been commenced some time previously by the Hokkaido Government for the fishery purpose. The measurement at the different places, whose positions are indicated on the maps, figs. 1, 3, and 4, was made by the present author in conjunction with Messrs. Toyokra and Kajinuma, directors of the meteorological observatories of Sapporo and Hakodate respectively, and their assistants, in 1910 and 1911, as follows:—

TABLE VII. Mean Group Values of the Level Gauge Reading at Different Places on the Coast of the Lake of Toya.

Date. (Month, Day.)	Level Gauge Reading at					Difference.	
	(I) Tokotan.	(II) Takinoue.	(III) West Kohan School.	(IV) Naka-Toyo.	(V) Muke-Toya.	(III) and Mean of (I) and II).	(II) and (III)
1910	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*
VIII, 6	4.38	3.33	1.91	—	—	1.85	1.42
7	—	—	1.66	—	—	—	—
8	—	3.38	1.51	—	—	—	1.87
..	4.50	—	1.51	—	—	—	—
9	—	3.38	1.47	—	—	—	1.91
10–11	4.45	3.45	1.35	—	—	2.60	2.10
12–15	4.15	3.48	1.25	—	—	2.77	2.23
16–19	4.56	3.48	1.09	—	—	2.93	2.39
20–24	4.46	3.40	0.91	—	—	2.92	2.49
25–31	4.40	3.40	0.85	—	2.05	3.05	2.55
IX, 1–7	4.33	3.31	0.81	—	2.02	3.01	2.50
8–14	4.20	3.21	0.77	0.37	1.95	2.94	2.44
15–20	4.10	3.13	0.71	0.31	1.85	2.91	2.42
21–29	4.03	—	—	0.17	—	—	—
XI, 8–11	3.28	2.13	0.10	—	—	2.61	2.03
1911 IV, 14–28	—	1.97	− 0.11	—	—	—	2.08
XI, 13–15	3.10	2.10	− 0.03	—	—	2.69	2.13

Tokotan (S.W. coast of the lake): Aug. 3rd to Sept. 24th, and Nov. 8th and 9th, 1910; 13th–15th, Nov., 1911.

Takinoue (S.E. coast of the lake): Aug. 3rd to Sept. 19th, and 10th and 11th, Nov., 1910; 14th-28th, April, and 13th-15th, Nov., 1911.

West Kohan School (S.S.E. coast of the lake): Aug. 3rd to Sept.

22nd, and Nov. 10th, 1910; 14th to 28th, April, and 13th-15th, Nov., 1911.

Naka-Toya (N.E. coast of the lake): 9th to 29th, Sept. 1910.

Muko-Toya (N.W. ,, ,,): Aug. 30th to Sept. 20th, 1910.

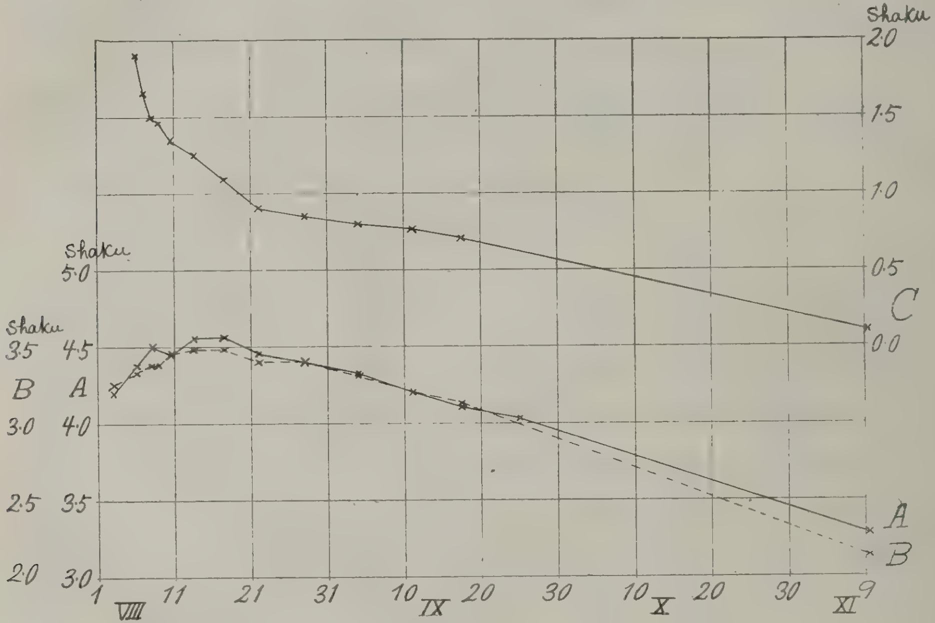


Fig. 11. Height Variation of the Surface of the Lake of Toya at different points of the Coast: Level Gauge Readings at the West Kohan School, Tokotan and Takinoue, Aug. 3rd to Nov. 11th, 1910.

A......Tokotan. B......Takinoue. C......W. Kohan School.

The level-gauge readings at the different places refer to the respective arbitrary zeros.

1 *shaku* = $\frac{1}{3}\times$ metre = 0.994 foot.

The results of the observations are contained in Table X, the readings of the lake surface height at the 5 coast stations being referred not to one common datum plane, but to the arbitrary zeros of the respective level gauge posts. As will be seen from Table VII, which is based on Table X and gives the mean values deduced by conveniently grouping the successive observations, the lake water at Tokotan and Takinoue was raised about 0.2 *shaku**

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* 1 *shaku* = 0.994 foot = $\frac{1}{3.3}\times$1 metre.

in the course of the first 20 days of Aug. (1910) and was thereafter gradually lowered, the amount of decrease reaching 1.3 *shaku* on the 10th of Nov. next. On the other hand, at the West Kohan school the lake level was continually lowered since the commencement, the level-gauge indicating the decrease of 1.25 *shaku* in the interval of Aug. to Nov., 1910. Further, a comparison of the height readings at Naka-Toya with those at Tokotan and Takinoue indicates that the increase and decrease of the water level was nearly equal at these 4 places, which consequently must have sufferred no considerable height variation, or, if any, simultaneously and similarly. (See Table VIII.) As illustrated in fig. 11, the height variation of the lake level was almost exactly identical at Tokotan and Takinoue, but was much dissimilar between these two places and the west Kohan school.

TABLE VIII. Comparison of Lake Level Variation at Tokotan, Takinoue, Naka-Toya, and Muko-Toya.

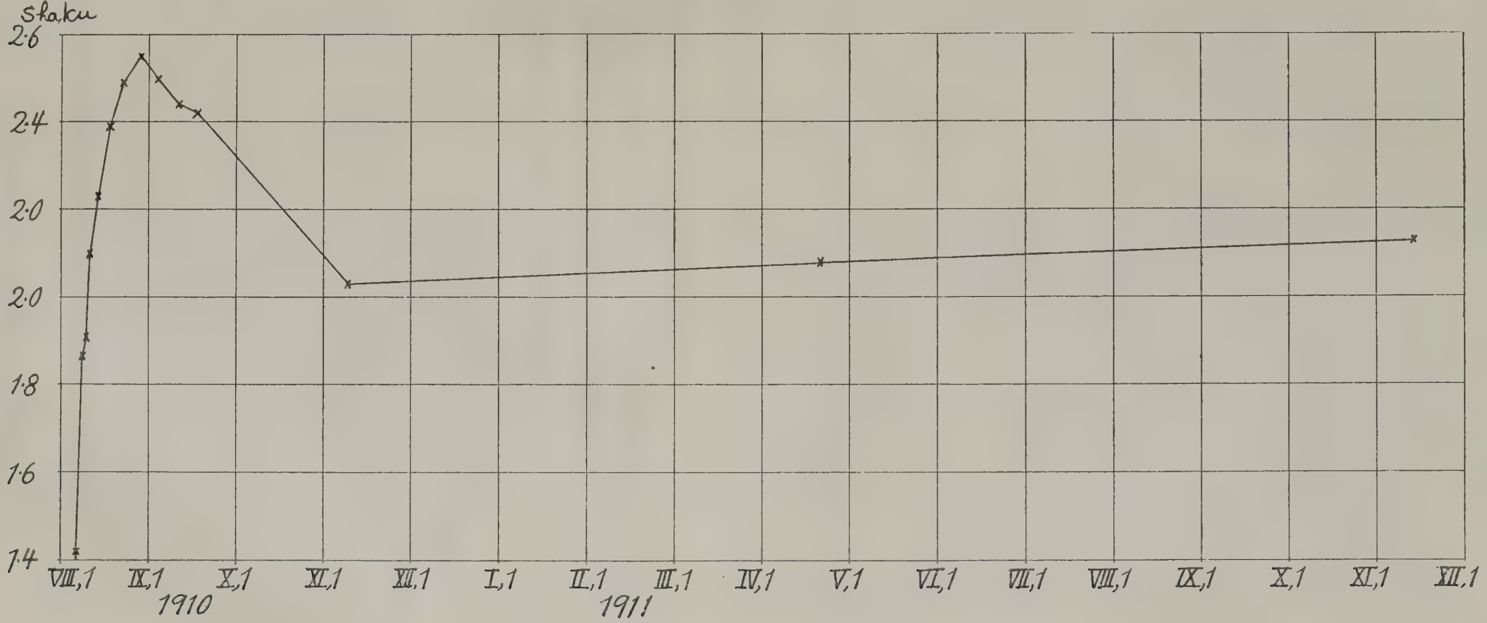
Time Epoch. (1910)	Place of Observation.	Lake Level Variation.	
		shaku	
1st–7th......15th–20th, Sept.	Takinoue	0.18	Decrease.
	Muko-Toya	0.17	„
9th–14th......21st–29th, „	Tokotan	0.17	„
	Naka-Toya	0.20	„
9th & 10th......19 & 20th, „	Naka-Toya	0.12	„
	Muko-Toya	0.16	„
8th–10th......16th & 17th, Aug.	Tokotan	0.09	Increase.
	Takinoue	0.10	„
16th–19th, August. ...... 8th–11th, November.	Tokotan	1.28	Decrease.
	Takinoue	1.35	„

In Table XI, the height of the lake surface at Tokotan, Takinoue, and the West Kohan school, are referred to the readings of the graduated level-gauge posts at the respective places on Sept.

Fig. 12. Elevation of the West Kohan Coast :

Reading at the West Kohan School referred to that at Takinoue, Aug. 3rd, 1910, to Nov. 15th, 1911.

1 *shaku* = $\frac{1}{3}$ × metre = 0.994 foot.



18th and 19th, 1910, as about that time the rate of the height variation became slight. The difference between the height readings at the West Kohan school and the mean of the corresponding values at Tokotan and Takinoue, which may be taken as indicating the real amount of the elevation of the ground at the former place, is, in the last column of Table XI, referred to Aug. 6th as the starting epoch.* Again, in the last column of Table X, is given the difference between the corresponding height readings at Takinoue and West Kohan school. The course of the height variation represented by this latter difference is illustrated in fig. 12. The mean elevation reached the maximum some 33 days after the first eruption, namely, on about Aug. 27th; the amount of the rise of the ground between the latter date and the 6th of the same month being 1.13 *shaku*=34.2 cm., with the average rate of nearly 1 cm. per day. Of course the elevation was at first much quicker, there being a rise of 0.68 *shaku*=20.6 cm. in the course of the 4½ days between the 6th and the 10th-11th of Aug. (1910), with the rate of 4.6 cm. per day. On the 6th, when the fact of the vertical change of the ground was first brought into notice, the elevation had already reached 1 m., giving for the 12 days since the 25th of July, the day of commencement of the eruption, the average rate of about 8 cm. per day.

The restitution of the elevated coast at the West Kohan school set in after about Aug. 27th and continued on regularly, the amount of the total depression reached on Nov. 8th-11th, in the course of the 75 days, being 0.52 *shaku*=15.8 cm., with the average of 0.2 cm. per day.

Thereafter the coast in question ceased to exhibit prominent

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* The elevation of the ground at the West Kohan school thus deduced, has, on p. 26, the Bulletin, Vol. V, No. 3, been converted into cm.

TABLE IX. Relative Level-Gauge Readings on 11th-19th, Aug. 1910.

Date (VIII, 1910.) / Place of Observation.	11	12	13	14	15	16	17	18	19
	shaku	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*	*shaku*
W. Kohan School.	0.00	0.05	0.10	0.10	0.14	0.21	0.20	0.30	0.35
60 feet to the west.	0.00	0.06	0.16	0.24	0.45	0.62	0.74	0.91	1.02

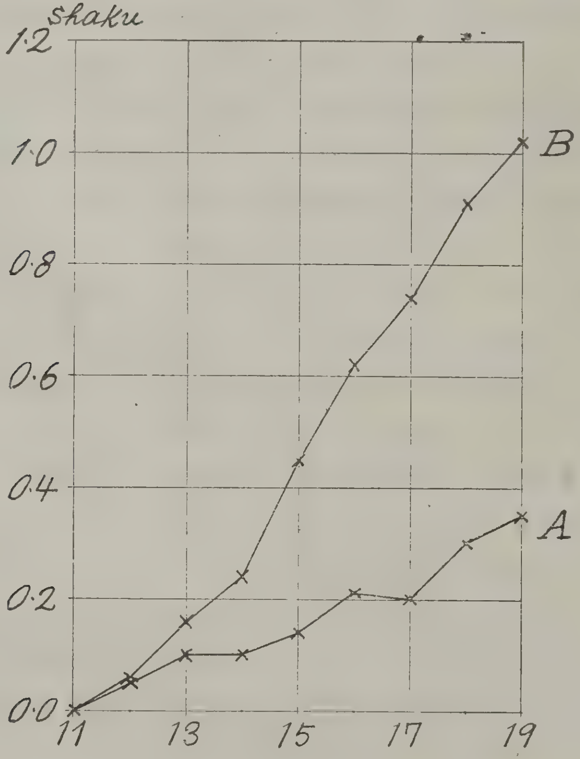


Fig. 13. Elevation of the West Kohan Coast: Change Amount at Neighbouring Points.

Level-gauge reading difference, Aug. 11th-19th, 1910:
(A), In front of the West Kohan School;
(B), At 60 feet to the West of A.

1 *shaku* = $\frac{1}{3}$ × metre = 0.994 foot.

changes, and was found, in April and November of the next year, 1911, to have nearly the same height as in Nov. 1910. The rate of the height decrease ought naturally to be less than that of the height increase, as the extent of the restitution depression was limited to only one-ninth of the elevation.

The amount of the elevation was not uniform along the length of the affected West Kohan coast. Thus, the height readings taken of a graduated level-gauge erected 60 feet to the west of that in front of the West Kohan school indicated in Aug., 11th to 19th, 1910, an elevation about 2.6 times greater than in the case of the latter, as shown in Table IX and fig. 13.

9. Eruption and lake water. The water in the lake of Toya began to become unusually abundant from about the time of the Usu-san eruption in the latter part of July (1910). Consequently the flow in the Sobets river, the only outlet of the lake, was so much increased that in the town of Sobets, where the stream is narrow and about 50 feet in width, the water rose 2 feet higher than in ordinary times, this being an event quite unprecedented. Again, at the Tokotan district, a few houses on the lake shore were very nearly flooded; while the beach of the Kwannon-jima islet in the Toya, ordinarily 10 feet in width, was, at the time of my visit in the begining of Aug. (1910), was entirely submerged, some of the drooping tree branches being also immersed in water. These facts seem to indicate that the lake water increase of about 1 foot at the time of the eruption was rather the consequence of the latter, and not due simply to the annual height variation of the lake surface. As the level gauges at Tokotan and Takinoue showed no marked fluctuations in the height of the surface till the latter part of Aug., the water in the Toya lake and the flow in the Sobets river is to be assumed to have sufferred no great decrease for about 1 month after the commencement of the eruption. At the time of my second visit, on Nov. 10th (1910), the water height at Sobets as well as at Tokotan and Takinoue was found brought back practically to the ordinary condition.

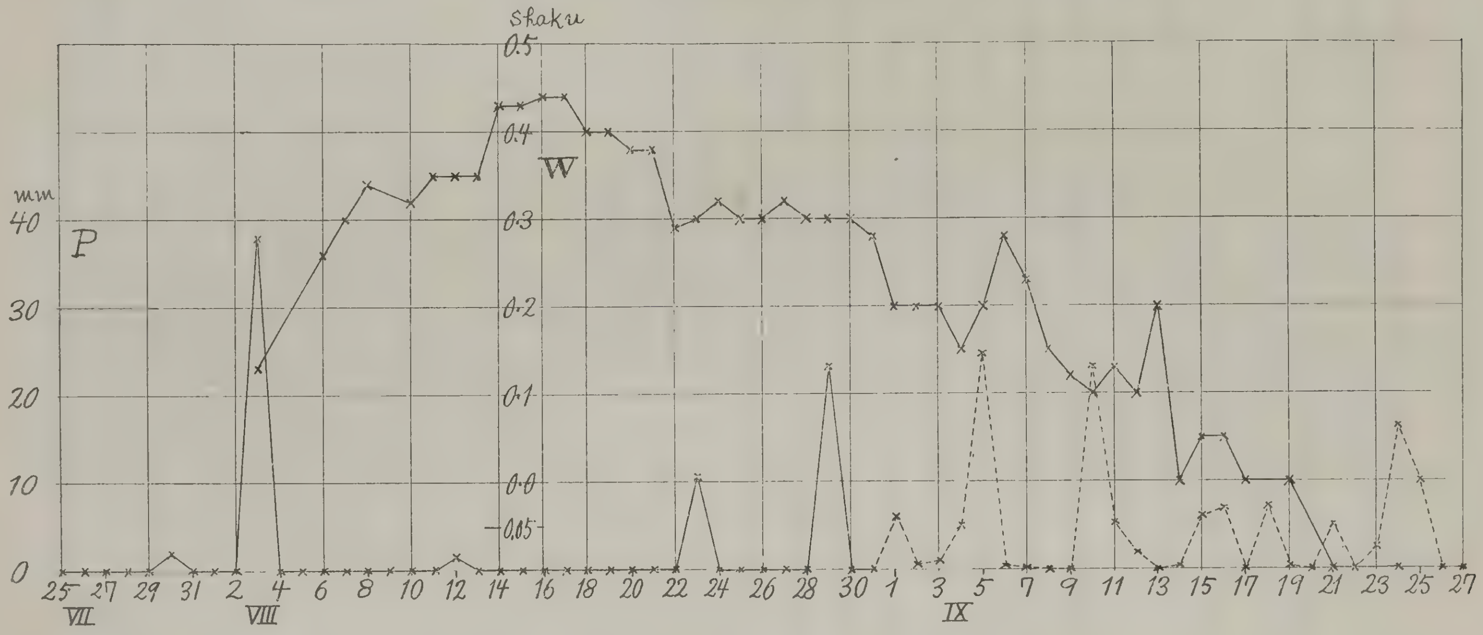
According to Tables X and XI, the lake surface was elevated at Tokotan and Takinoue 0.38 *shaku* (=11.5 cm.) and 0.25 *shaku* (=7.6 cm.) respectively, in the course of the 11 to 13 days after Aug. 3rd (1910), the maximum height being reached on Aug. 14th to 16th. Thereafter the lake surface continued to be lowered, the depression amounting in Nov. (1910) to 1.5 *shaku*= 45.5 cm.

The full meaning of this marked water decrease in November (1910), which is to be regarded as quite special to the occasion under consideration, will be realized by referring to the annual variation of the surface height of the Shikots lake in the Tarumai volcanic district. According to the Shikots level-gauge observations made during the 10 years before the completion of the water-power dam, namely, Jan. 1900 to April 1910, the mean monthly water level in August was 0.147 *shaku* (=4.5 cm.) *lower* than in November; while according to similar observations during the next 10 years, July 1910 to Dec. 1919, after the completion of the dam, the mean level in August was 0.422 *shaku* (=12.8 cm.) *lower* than in November. Again, in the case of the shallow O-numa lake at the S. foot of the Komaga-take volcano, on the opposite side of the Volcano Bay, the mean monthly height of the water surface deduced from the observations in the 6 years, 1913 to 1919, was 1.03 *shaku* (=31.2 cm.) *lower* in August than in November. The occurrence of the maximum level of the Toya lake in Aug. 1910 was thus different from the usual habit of the other volcanic lakes in the S.W. part of Hokkaido.

Fig. 14. Variation of the Height of the Lake Surface and the Amount of Precipitation, in July and August, 1910.

W.........Lake level, meaned from the observations at Tokotan and Takinoue.
(1 *shaku*=0.994 foot.)

P.........Amount of precipitation : full line for Abuta, and dotted line for Sobets.



10. Precipitation and lake water. In Table XII is given the daily amount of precipitation observed in July-October, 1910, at the village office of Abuta and the elementary school of Sobets; these two places being to the S.W. and to the S.E. of the Toya, respectively at distances of 4 and 1 km. from the nearest lake coast. The precipitation was small during July and Aug., the total amounts for these two months being at Abuta 14.6 mm. and 73.2 mm. respectively. The precipitations in September and October next were great, being at Sobets respectively 122.5 mm. and 35.7 mm. Fig. 14 graphically illustrates the course of the variation of the height of the lake surface and of the amount of the precipitation in Aug. and Sept. (1910). It is difficult to conceive the precipitation on Aug. 3rd as the agency, which caused the marked elevation of the water level at the middle of Aug. In connection with the question of the precipitation, the following account of the daily weather and the condition of the lake level at Naka-Toya, on July 22nd-30th (1910), is of a special interest:—

22nd. Fair; warm in the evening.
23rd. Cloudy.
24th. Fair.
25th. Fair: strong S.E. wind.
26th. Cloudy.
27th. Fair; explosive sounds heard between 1 and 4 a.m. There were rumours of an overflooding of the lake water, and some of the people fled to the hilly parts. Level-gauge erected at the coast.
28th. Rainy. At 11 a.m., strong rain and thunders. At 6 p.m., the level gauge indicated 0.3 *shaku* (=9 cm.) rise of water surface.
29th. Rainy. At 6 a.m. the level gauge reading was 0.3 *shaku* higher than on the previous day.

30th. Rainy. There was a further water increase of 0.3 *shaku*.

Thus, at Naka-Toya, there was an increase of the aggregate amount of about 0.9 *shaku*=27.3 cm. during the three days of July 28th-30th. This rise of the water surface might be related to the rainy condition of the days in question, but certainly not to a significant degree, as may be inferred from the following instances. According to Tables XII and X, there were at Sobets on Sept. 5th and 10th the precipitation of the amounts of 24.6 mm. and 23.2 mm. respectively. Yet none of the level-gauges at Tokotan, Takinoue, Naka-Toya, and Muko-Toya indicated any special water increase on those days or on the following days.

11. Cause of increase of lake water. The increase of the water of the lake of Toya considered in §9 might be due to the following three circumstances:–(i), the precipitation; (ii), flowing in of the volcanic mud; and (iii), the elevation of the lake bottom. The amount of the precipitation (i) in the vicinity of the lake at the time of the eruption seems, as mentioned in §10, not sufficient to produce the water increase in question. With respect to (ii), there were poured very often mud streams from some of the craterlets of the 1910 eruption into the Toya, the entire lake water being thereby turned turbid and light-greenish in colour. The total amount of the mud thus carried into the lake was, however, comparatively small. Even the volume of the volcanic material carried down by the mud stream from the craterlet at the S. base of the W. Maru-yama, which was the greatest of the kind in the 1910 eruption, was probably not much above 300×300×3 m.=1/3000 c. km. The contribution by the other smaller mud streams were much more insignificant. As the area of the Toya lake is about 73 sq. km., the inflow of the muds taken together would have raised at the most the water level only by 1 cm. Lastly, with respect to the change of the lake bottom (iii), let us imagine an area of 10 sq. km. of the latter was elevated 2 m. The lake surface would then be raised about 30 cm. or 1 *shaku.* If the elevation of the same area be 3 m., the water surface would be raised 45 cm. = 1½ *shaku.* Thus the elevation of the lake bottom of the magnitude here assumed can fully account for the actual change of the height of the water surface. This hypothesis is moreover in accordance with the probable reduction of the depth of the water revealed by the soundings (§7).

12. Temperature of lake water. For the sake of reference I give in Table XIII the temperature of the Tôya lake in Aug., Sept., and Nov., 1910, at Tokotan, Takinoue, and West Kohan; the measurement having been made in each case at the distance of about 2 metres from the coast, and at the depth of about 30 cm. below the water surface. The mean results were as follows:—

Time Interval. (1910)	Lake Water Temperature. (I) Maximum.	(II) Minimum.	(III) Mean.	(IV) Air Temperature.	Difference, (III)-(IV)
(1) VIII, 2nd–14th.	21°.7 C.	18°.1 C.	20°.0 C.	21°.9 C.	– 1°.9
(2) ,, 15th–23rd.	22.6	21.2	21.7	23.0	– 1.2
(3) ,, 24th–31st.	24.0	22.4	23.5	22.2	1.2
(4) IX, 1st–10th.	22.6	21.0	21.9	19.8	2.0
(5) XI, 8th–11th.	13.2	11.7	12.2	7.9	4.4

Thus the water temperature was highest in the (3) epoch, Aug. 24th-31st, the corresponding mean value being somewhat higher than those of the air temperature in the different epochs. (See fig. 15.) It is hereby to be remarked that the water tempe-

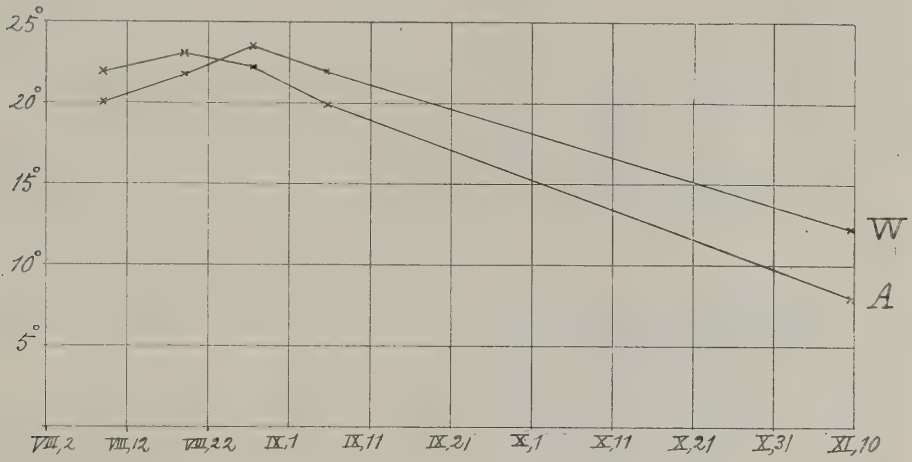


Fig. 15. Temperature of the Lake Water compared to that of Air, Aug. to Nov. 1910.
W......Lake water temperature. A......Air temperature.

rature was thus maximum in the latter part of the month of August (1910), when the elevation of the West Kohan coast was at the maximum limit, and when the process of formation of the New Mountain was most active. These circumstances seem to indicate that cracks were formed at the time of the eruption also at the bottom of the Toya, thereby introducing some hot waters from below and increasing to a certain extent the temperature of the lake water. The existence of the submerged hot springs is probable, as the lake of Toya does not freeze in winter. The hot spring, at the lake coast to the north of the West Maru-yama, brought into existence after the eruption and at present 42°C. in temperature apparently belongs to the category here supposed.

13. The Volcano Bay. The Volcano Bay, or Uchiura-wan, which is nearly circular and has the diameter of about 50 km., owes probably its origin to a volcanic depression. It is continued at the S.E. to the Pacific ocean by an opening 27 km. wide, at whose N.E. and S.W. ends are placed the port of Muroran and the volcanic mass of the Komaga-take respectively. In spite of the large extension the bay is shallow and has the maximum depth of only 59 fathoms=107 m. As will be seen from fig. 16, the contour lines of the bottom, which is on the whole flat, are not arranged symmetrically with respect to the centre, the deepest area being situated at the western part of the bay. This depth eccentricity may be assumed to be the result of a slight elevation of the eastern part of the bay along the straight line joining the Usu-san and the Nakano-shima in the Toya lake, on the north, with the Komaga-take volcano on the south.

14. Relation of Volcano Bay to Toya and Shikots lakes.

The lake of Shikots, situated between the two volcanoes of the Tarumai-dake and the Eniwa-dake, about 76 sq. km. in area, owes its origin also to a volcanic depression and is flat-bottomed and deep, with the maximum water depth of 358 m. A fact of special interest with respect to the Volcano Bay is the approximate identity of the bottom depth with those of the two volcanic lakes of Toya and Shikots, as follows:—

Bottom of the	Volcano Bay	107 m.	below sea level.
,,	Toya lake	103 m.	,,
,,	Shikots lake	110 m.	,,

The depth of about 110 m. below the sea level seems to indicate the limit of the volcanic depression in the S. W. part of Hokkaido. (See the Bulletin, Vol. VIII, No. 4.)

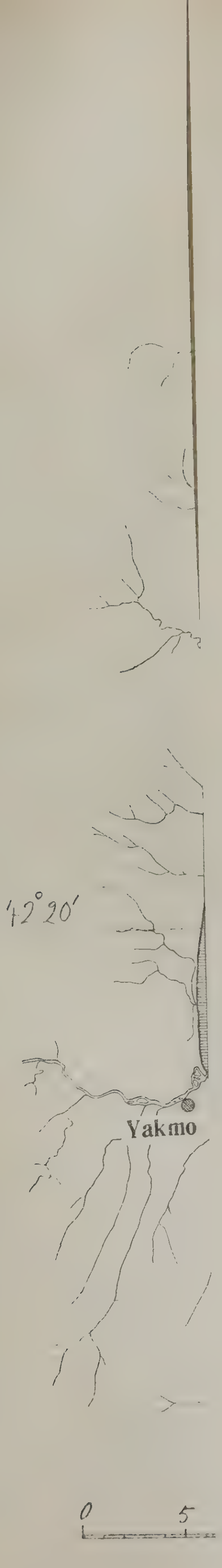


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Fig. 16. Isobathymetric Chart of the Volcano Bay.

(Based on the Imperial Navy Hydrographic Chart No. 17. published in 1904.) Depth in fathoms.

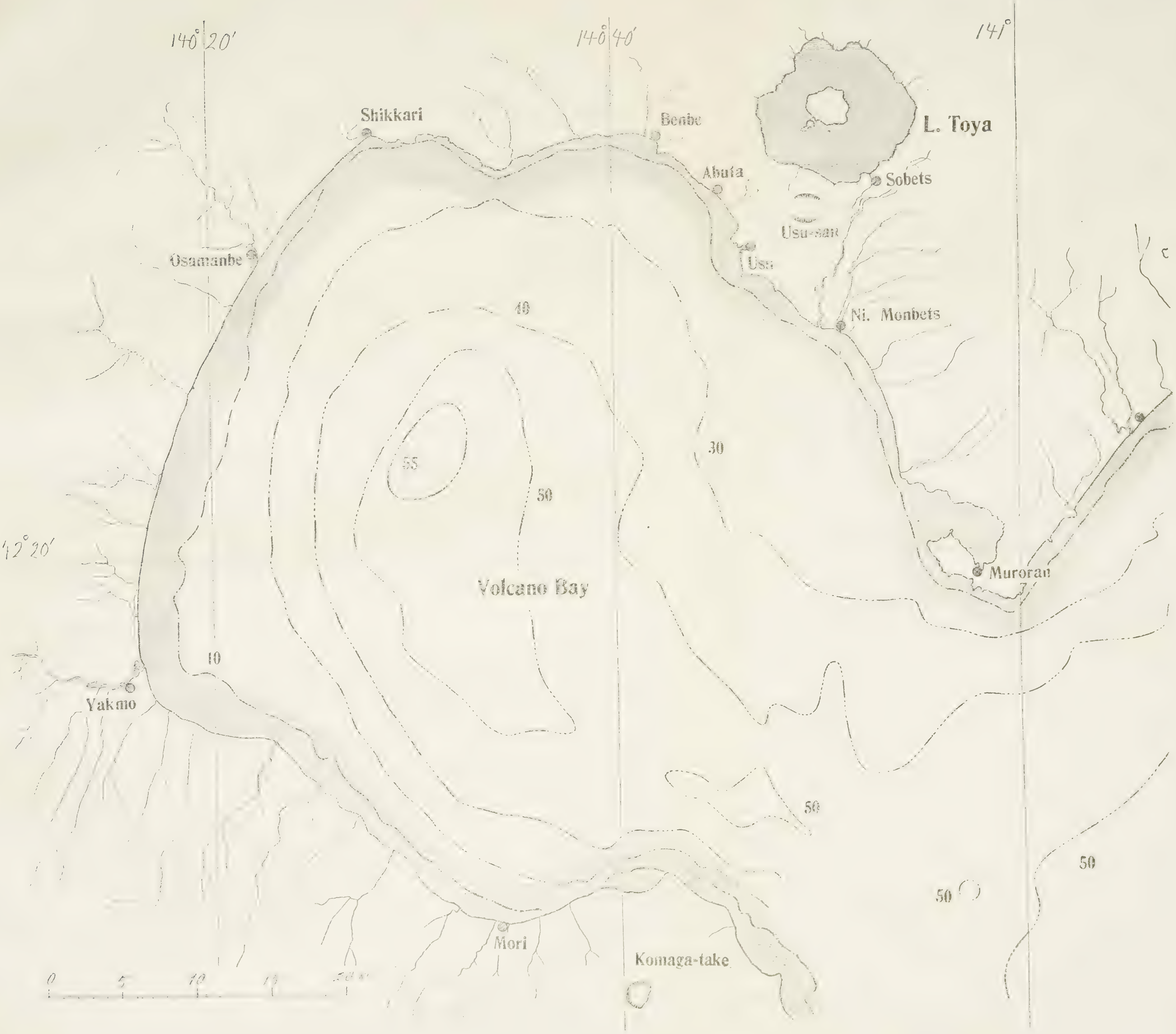

TABLE X. Height of the Water Surface observed at Different Places on the Coast of the Lake of Toya, Aug. 3rd, 1910, to Nov. 15th, 1911.

(The reading at each place is referred to the arbitrary zero of the level gauge.)

Date.	Tokotan.	Takinoue.	West Kohan School.	Naka-Toya. (6 A.M.)	Muke-Toya. (6. A.M.)	Weather.	Precipitation.
VIII, 1910.	*shaku.*	*shaku.*	*shaku.*				mm.
3	4.20 ($10\frac{1}{4}$ A.M.)	3.25 ($4\frac{2}{3}$ A.M.)					
6	4.38	3.33	1.91				
7	—	—	1.66				
8	4.50 ($11\frac{5}{6}$ A.M.)	3.38 ($8\frac{2}{3}$ A.M.) 3.38 ($6\frac{2}{3}$ P.M.)	1.51				
9	—	3.38 ($11\frac{1}{6}$ A.M.)	1.47				
Mean.	**4.35**	**3.35**					
10	4.45 ($10\frac{1}{2}$ A.M.)	3.39 ($7\frac{3}{4}$ A.M.)	1.35 (2 P.M.)				
11	—	3.45	1.35			Rainy.	
Mean.	4.45	**3.42**	**1.35**				
12	—	3.45	1.30			Rainy.	
13	—	3.45	1.25			,,	
14	4.55 (4 P.M.)	3.50	1.25			,,	
15	4.55 (1 P.M.)	3.50	1.21			Cloudy.	
Mean.	**4.55**	**3.48**	**1.25**				
16	4.58 (2 P.M.)	3.50	1.14			Clear.	
17	4.57 (10 A.M.)	3.50	1.15			,,	
18	4.55 (11 A.M.)	3.45	1.05			,,	
19	4.55 (1 P.M.)	3.45	1.00			,,	
Mean.	**4.56**	**3.48**	**1.09**				
20	4.55	3.40	0.95			Cloudy.	
21	4.55	3.40	0.90			,,	
22	4.40	3.38	0.88			,,	
23	4.40	3.40	0.92			Rainy.	
24	4.40	3.44	0.90			Clear.	
Mean.	**4.46**	**3.40**	**0.91**				
25	4.40	3.40	0.86			Cloudy.	
26	4.40	3.40	0.84			,,	
27	4.40 (9 A.M.)	3.43	0.84			Fair.	
28	4.40	3.40	0.84			,,	
29	4.40 (11 A.M.)	3.40	0.85			Rainy.	8.5

TABLE X. (*Cont.*)

Date.	Tokotan.	Takinoue.	West Koban School.	Naka-Toya. (6. A.M.)	Muke-Toya. (6. A.M.)	Weather.	Precipitation.
VIII, 1910.	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*		mm.
30	4.40 (9 A.M.)	3.39	0.87		2.05	Cloudy.	0.0
31	4.40 (9 A.M.)	3.35	0.86		2.05	,,	0.9
Mean.	**4.40**	**3.40**	**0.85**		**2.05**		**3.1**
IX, 1910.							
1	—	3.30	0.80		2.05	Rainy.	6.0
2							
3	—	3.30	0.80		2.03	Rainy.	1.0
4	—	3.25	0.80		2.00	,,	4.9
5	—	3.30	0.80		1.95	,,	24.6
6	4.35 (11 A.M.)	3.40	0.86		2.03	,,	0.2
7	4.30 (11 A.M.)	3.35	0.81		2.02	,,	0.1
Mean.	**4.33**	**3.31**	**0.81**		**2.02**		**5.3**
8	—	3.25	0.78	—	1.97	Cloudy.	—
9	4.20 (4 P.M.)	3.23	0.75	0.40	1.95	,,	—
10	4.20	3.20	0.75	0.40	1.93	Rainy.	23.2
11	4.20	3.25	0.77	0.38	1.94	,,	5.3
12	4.20	—	—	0.35	1.94	,,	1.8
13	—	3.30	0.80	0.35	1.95	—	—
14	—	3.10	0.75	0.35	1.94	Fair.	0.3
Mean.	**4.20**	**3.21**	**0.77**	**0.37**	**1.95**	—	**4.4**
15	—	3.15	0.75	0.32	1.91	Rainy.	6.1
16	—	3.15	0.70	0.32	1.90	Clear.	6.9
17	4.10	—	0.70	0.32	1.85	,,	—
18	—	—	0.70	0.30	1.85	Fair.	7.3
19	4.10	3.10	–	0.30	1.80	Rainy.	0.3
20	—	—	—	0.27	1.77	Fair.	—
Mean.	**4.10**	**3.13**	**0.71**	**0.31**	**1.85**		**3.4**
21	4.00	—	—	0.20		Fair.	5.0
22	—	—	0.62	0.20		Rainy.	0.0
23	—	—	—	0.20			2.4
24	4.00	—	—	0.20			16.3
25	—	—	—	0.15			10.0
26	—	—	—	0.15			0.0
27	—	—	—	0,15			0.0
28	—	—	—	0.13			0.0

TABLE X. (*Cont.*)

Date.	Tokotan.	Takinoue.	West-Koban School.	Naka-Toya. (6. A.M.)	Muke-Toya. (6. A.M.)	Weather.	Precipitation.
IX, 1910.	*shaku.*	*shaku.*	*shaku.*	*shaku.*			mm.
29	—	—	—	0.13			0.0
Mean.	**4.03**	—	—	**0.17**			**3.7**
XI, 1910.							
8	3.25 ($9\frac{5}{8}$ A.M.)	—	—				
9	3.30	—	—				
10	—	2.10 ($9\frac{1}{2}$ A.M.)	0.10 ($4\frac{1}{2}$ P.M.)				
11	—	2.15 (2 P.M.)	—				
Mean.	**3.28**	**2.13**	0,10				
IX, 1911.							
14		—	—			Fair.	
15	*	1.68 (8 A.M.)	—			"	
16		—	—			"	
17		1.78	-0.40 (11 A.M.)			Slightly rainy. Strongly windy.	
18			-0.10			Stormy.	
19		2.03 (6 P.M.)	-0.10				
20		1.96 (7 A.M.)	-0.15 ($7\frac{1}{2}$ A.M.) -0.10 (4. P.M.)				
21		—	-0.02 ($7\frac{2}{3}$ A.M.)				
22		—	-0.15 ($7\frac{2}{3}$ A.M.)				
23		—	-0.10 (9 A.M.)				
24		2.03 (6 P.M.)	-0.20 (8 A.M.)				
25		—	-0.02 (9 A.M.)				
26		—	-0.05 (9 A.M.)				
27		—	-0.02 (3 P.M.)				
28		2.04 (Noon.)	0.00 ($7\frac{1}{2}$ A.M.)				
Mean.		**1.97** (*excepted.)	**-0.108**				
XI, 1911.							
13	3.10 ($11\frac{1}{4}$ A.M.)	—	0.00 ($4\frac{1}{3}$ P.M.)			Rainy, windy.	
14	—	2.10 ($9\frac{1}{2}$ A.M.)	-0.05 ($10\frac{1}{4}$ A.M.)			Snowy, windy.	
15	—	2.10 (8.25 A.M.)	—			Clear, calm.	
Mean.	**3.10**	**2.10**	**-0.025**				

TABLE XI. Height of the Lake Surface at Tokotan, Takinoue, and West Kohan School, Aug. 3rd, 1910 to Nov. 15th, 1911.

(The height reading at each place in referred to that on Sept. 18th-19th as zero.)

Date.	Tokotan.	Takinoue.	Mean of Tokotan and Takinoue. **I**	West Kohan School. **II**	Difference **I − II = III**	shaku **III + 0.95 = III′**
1910.	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*
VIII, 3	0.10	0.15	0.13	—	—	—
4	0.40	0.28	0.34	—	—	—
5	—	—	—	—	—	—
6	0.28	0.23	0.26	1.21	− 0.95	0.00
7 { 0½ P.M.	—	—	0.30	1.06	− 0.76	0.19
7 { 6 P.M.	—	—	0.31	0.86	− 0.55	0.40
8 { 8 A.M.	—	0.28	0.28	0.81	− 0.53	0.42
8 { Noon.	0.40	—	0.40	0.81	− 0.41	0.54
9 (Noon).	—	0.28	0.28	0.77	− 0.49	0.46
10	0.35	0.29	0.32	0.65	− 0.33	0.62
11	—	0.35	0.35	0.65	− 0.30	0.65
12	—	0.35	0.35	0.60	− 0.25	0.70
13	—	0.35	0.35	0.55	− 0.20	0.75
14	0.45	0.40	0.43	0.55	− 0.12	0.83
15	0.45	0.40	0.43	0.51	− 0.08	0.87
16	0.48	0.40	0.44	0.44	0.00	0.95
17	0.47	0.40	0.44	0.45	− 0.01	0.94
18	0.45	0.35	0.40	0.35	+ 0.05	1.00
19	0.45	0.35	0.40	0.30	+ 0.10	1.05
20	0.45	0.30	0.38	0.25	+ 0.13	1.08
21	0.45	0.30	0.38	0.20	+ 0.18	1.13
22	0.30	0.28	0.29	0.18	+ 0.11	1.06
23	0.30	0.30	0.30	0.22	+ 0.08	1.03
24	0.30	0.34	0.32	0.20	+ 0.12	1.07
25	0.30	0.30	0.30	0.16	+ 0.14	1.09
26	0.30	0.30	0.30	0.14	+ 0.16	1.11
27	0.30	0.33	0.32	0.14	+ 0.18	1.13
28	0.30	0.30	0.30	0.14	+ 0.16	1.11
29	0.30	0.30	0.30	0.15	+ 0.15	1.10
30	0.30	0.29	0.30	0.17	+ 0.13	1.08
31	0.30	0.25	0.28	0.16	+ 0.12	1.07

TABLE XI. (*Cont.*)

Date.	Tokotan.	Takinoue.	Mean of Tokotan and Takinoue. I	West Kohan School. II	Difference I − II = III	shaku III + 0.95 = III'
1910.	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*	*shaku.*
IX, 1	—	0.20	0.20	0.10	+ 0.10	1.05
2	—	0.20	0.20	0.13	+ 0.07	1.02
3	—	0.20	0.20	0.10	+ 0.10	1.05
4	—	0.15	0.15	0.10	+ 0.05	1.00
5	—	0.20	0.20	0.10	+ 0.10	1.05
6	0.25	0.30	0.28	0.16	+ 0.12	1.07
7	0.20	0.25	0.23	0.11	+ 0.12	1.07
8	—	0.15	0.15	0.08	+ 0.07	1.02
9	0.10	0.13	0.12	0.05	+ 0.07	1.02
10	0.10	0.10	0.10	0.05	+ 0.05	1.00
11	0.10	0.15	0.13	0.07	+ 0.06	1.01
12	0.10	—	0.10	—	—	—
13	—	0.20	0.20	0.10	+ 0.10	1.05
14	—	0.00	0.00	0.05	− 0.05	0.90
15	—	0.05	0.05	0.05	0.00	0.95
16	—	0.05	0.05	0.00	+ 0.05	1.00
17	0.00	—	0.00	0.00	0.00	0.95
18	—	—	—	0.00	0.00	0.95
19	0.00	0.00	0.00	—	—	—
20	—	—	—	—	—	—
21	− 0.10	—	− 0.10	—	—	—
22	—	—	—	− 0.08	—	—
23	—	—	—	—	—	—
24	− 0.10	—	− 0.10	—	—	—
XI, 8	− 0.85	—	− 0.85	—	—	—
9	− 0.80	—	− 0.80	—	—	—
10	—	− 1.00	− 1.00	− 0.60	− 0.40	0.55
11	—	− 0.95	− 0.95	—	—	—
1911.						
IV, 17—28	—	− 1.03	− 1.03	− 0.81	− 0.22	0.73
XI, 13—15	− 1.00	− 1.00	− 1.00	− 0.73	− 0.27	0.68

TABLE XII. Precipitation at Abuta and Sobets, May to October, 1910.

Day. (1910)	Abuta.		Sobets.		
	July.	August.	August.	September.	October.
	mm.	mm.	mm.	mm.	mm.
1	—	—		6.0	0.0
2	—	—		0.4	0.0
3	—	38.0		1.0	0.1
4	—	—		4.9	0.0
5	—	—		24.6	0.0
6	—	—		0.2	0.0
7	4.0	—		0.1	0.0
8	4.6	0.0		—	5.8
9	1.0	0.0		—	0.3
10	1.5	—		23.2	0.0
11	0.5	—		5.3	3.8
12	—	1.5		1.8	0.0
13	—	—		—	0.0
14	—	—		0.3	0.0
15	—	—		6.1	0.0
16	—	—		6.9	0.0
17	—	—		—	2.6
18	—	—		7.3	41.9
19	—	—		0.3	4.3
20	1.0	—		—	—
21	—	—		5.0	17.5
22	—	—		0.0	5.7
23	—	10.5		2.4	—
24	—	—		16.3	3.7
25	—	—		10.0	0.0
26	—	—		0.0	0.0
27	—	—		0.0	0.0
28	—	—		0.0	0.0
29	—	23.2	8.5	0.0	0.0
30	2.0	—	0.0	0.0	0.0
31	—	—	0.9		0.0
Sum.	**14.6**	**73.2**	—	**122.5**	**85.7**

TABLE XIII. Surface Water Temperature of the Lake of Toya, Aug. 2nd–Nov. 11th, 1910.

Place of observation.	Month.	Day.	Time.	Weather.	Wind.		Temperature.		
					Direction.	Intensity.	Air.	Water.	Difference.
							C.	C.	C.
Tokotan.	VIII	2	5. P.M.	Cloudy.	S.E.	Light.	—	20°.5	—
,,		3	10. A.M.	,,	S.E.	,,	19°.4	20.6	1°.2
Takinoue.		3	5.10 P.M.	,,	—	—	20.2	20.8	0.6
West Kohan.		6	5.45 P.M.	,,	S.E.	Gale.	20.6	18.1	2.5
,,		7	0.30 P.M.	Clear.	E.	Strong.	23.8	21.7	2.1
,,		,,	6. P.M.	,,	E.	,,	22.0	20.3	1.7
,,		8	7.40 A.M	Rainy.	E.S.E.	Gale.	21.4	20.0	1.4
,,		,,	0.5 P.M.	Cloudy.	E.S.E.	,,	22.7	20.4	2.3
,,		9	7.20 A.M.	Clear.	S.E.	,,	22.4	20.5	1.9
,,		,,	5. P.M.	,,	S.E.	,,	20.5	20.1	0.4
,,		10	7.20 A.M.	,,	S.E.	,,	20.8	20.5	0.3
,,		,,	2. P.M.	,,	S.E.	,,	22.0	19.0	3.0
,,		11	*	Rainy.	S.E.	,,	23.2	19.6	2.6
,,		12		,,	S.E.	Strong.	22.1	18.2	3.9
,,		13		,,	S.E.	Gale.	22.8	19.0	3.8
,,		14		,,	S.E.	Moderate.	24.0	20.0	4.0
			Mean.	....	....	....	**21.9**	**20.0**	(−) **1.9**
,,		15		Cloudy.	S.E.	Light.	26.2	21.1	5.1
,,		16		Clear.	N.W.	Moderate.	26.0	22.0	4.0
,,		17		,,	Calm.	—	21.0	22.1	1.1
,,		18		,,	N.W.	Lihgt.	21.0	21.8	0.8
,,		19		,,	W.	Moderate.	22.2	22.6	0.4
,,		20		Cloudy.	S.E.	Strong.	22.6	22 4	0.2
,,		21		,,	S.E.	,,	22.9	21.2	1.7
,,		22		,,	Calm.	—	24.2	21.2	3.0
,,		23		Rainy.	W.	Light.	20.7	21.3	0.6
			Mean.	....	....	....	**23.0**	**21.7**	(−) **1.2**

Table XIII. *(Cont.)*

Place of observation.	Month.	Day.	Time.	Weather.	Wind.		Temperature.		
					Direction.	Intensity.	Air.	Water.	Difference.
							C.	C.	
West Kohan.	VIII	24		Clear.	N.W.	Light.	21.6°	23.8°	2.2°
,,		25		Cloudy.	S.E.	Moderate.	22.3	22.4	0.1
,,		26		,,	S.E.	,,	—	—	—
,,		27		Fair.	E,	,,	—	—	—
,,		28		,,	E.	,,	—	—	—
,,		29		Rainy.	S.W.	Strong.	23.1	23.7	0.6
,,		30		Cloudy.	S.W.	,,	21.3	24.0	2.7
,,		31		,,	S.	Moderate.	22.8	23.4	0.6
			Mean.	....	....	....	**22.2**	**23.3**	(+) **1.2**
,,	IX	1		Rainy.	S.E.	Light.	17.8	21.3	3.5
,,		2		Cloudy.	W.	Moderate.	21.3	22.6	1.3
,,		3		,,	Calm.	—	18.9	21.0	2.1
,,		4		,,	S.E.	Moderate.	19.2	21.3	2.1
,,		5		Rainy.	S.E.	Light.	20.4	22.6	2.2
,,		6		,,	N.W.	,,	20.1	22.4	2.3
,,		7		,,	S.E.	Strong.	19.8	21.9	2.1
,,		8		Cloudy.	E.	Moderate.	21.5	22.0	0.5
,,		9		,,	W.	Light.	19.8	22.0	2.2
,,		10		,,	S.	Moderate.	19.6	21.4	1.8
			Mean.	....	....	....	**19.8**	**21.9**	(+) **2.0**
Tokotan.	XI	8	9.50 A.M.	Cloudy.	—	—	10.0	13.2	3.2
,,		9	10. A.M.	,,	N.	Strong.	7.6	12.0	4.4
Takinoue.		10	9.15 A.M.	Clear.	Calm.	—	6.6	12.0	5.4
,,		11	9. P.M.	Snowy.	N.E.	Strong.	7.2	11.7	4.5
			Mean.	....	....	....	**7.9**	**12.2**	(+) **4.4**

* Between Aug. 11th and Sept. 10th, the temperature measurement was made at 11 A.M. each day.

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目　次

論文及報告

頁
17. 地震に伴ふ發光現象に就て(英文)…………寺田寅彦 225
18. 地塊とその運動　第一報(英文)…………宮部直巳 256
19. 伊豆半島に於ける水準測量の結果に就いて(英文)…………坪井忠二 271
20. 海面大氣壓の擾亂によつて起る地動に就て(英文)…………妹澤克惟　西村源六郎 291
21. 彈性が深さに從て變る半無限固體上に傳はる一地震波(英文)…………妹澤克惟 310
22. 加速度地震計及び其の記象(佛文)…………石本巳四雄 316
23. 東京灣の出現(英文)…………矢部長克 333
24. 西南日本外帶とフオツサ・マグナとに於ける鮮新期初期末の地殼運動(英文)…………大塚彌之助 340
25. 相模國南西地域の堆積岩の岩石學的研究(二)(英文)…………津屋弘逵 353
26. 地震觀測報告(英文)………… 374

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17. *On Luminous Phenomena Accompanying Earthquakes.*

By **Torahiko TERADA,**

Earthquake Research Institute.

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Introduction.

Among the historical documents regarding severe earthquakes of the past, in Japan as well as in the other parts of the worlds, we find not infrequently some descriptions of remarkable luminous phenomena observed in the sky or on the ground before, during, or after the time of severe shocks. The phenomena were observed sometimes in the immediate vicinity of the epicentre and sometimes in very remote quarters. The descriptions of the form, colour, intensity, duration, motion and fluctuation of the luminosity observed are extremely variegated as the case may be. Still, it is interesting to remark that among these chaos of testimonies we may pick up almost parallel statements of quite independent witnesses. Thus, for example, we may cite a number of testimonies recorded in Galli's collection[1] of such data, which have their respective facsimiles among the Japanese data collected by Mr. Musya[2] and the present author. The agreement between the independent witnesses is not only referred to vague statements of the general features of the luminosity, but also to very detailed descriptions only capable for keen observers.

Notwithstanding these almost superfluously abundant materials of testimonies, the phenomena failed to attract any serious attention from the majority of seismologists, who apparently did not care for these documents at all. Even among those who came eventually to be confronted with some examples of the phenomena, skeptical opinions usually prevailed. Psychological or physiological illusions were often quoted, without proof. Distant lightnings, firebrands, camp-fires will be often mentioned, again mostly without proof. In the recent years, the possibility of short-circuiting of electric transmission lines has furnished a new item for these would-be causes of the phenomena in question. For those who does not spare the trouble of examining these documents with open mind, it will be, however, found difficult to discard the phenomena a priori as utterly unreal or independent from the earthquakes. Thu[illegible] example, A. Sieberg[3] spared a special chapter in his book on seismology for this phenomenon and states that there are some examples for which the usual explanation by the trivial causes seems to fail. He concludes by saying rightly enough that this luminous phenomenon is just the darkest chapter in seismology.

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[1] Ignazio Galli, " Raccolta e classificazione di fenomeni luminosi osservati nei terremoti, " *Bolletino della Società Italiana*, 14 (1910), 221.

[2] K. Musya, *Bull. E.R.I.*, 9 (1931), 177, (in Japanese, with English abstract).

Mr. Kinkiti Musya of our Institute was early interested with the luminous phenomena frequently described in the historical documents of our country concerning earthquakes and has made an excellent collection of these materials. The present writer was also of the opinion that the phenomena may be well worth a serious study and at least cannot be discarded as trivial without scrutiny. The Idu Earthquake of Nov. 26 1931 occurred just at this time when our attentions towards this particular phenomenon was ripening, and at once furnished us with so many conspicuous examples that any doubt about the physical reality of phenomena was completely removed and, moreover, their physical connection with the earthquake became a matter beyond any question. It seems, therefore, not without interest to attempt here a brief review of the literatures regarding the matter and also to make some discussions regarding them though the results of Mr. Musya's investigation are already published in the previous number of this Bulletin.

Occidental Literatures regarding the Phenomena.

Besides 148 examples given in Galli's collections and those cited in Sieberg's Erdbebenkunde, there are a number of other data at the hand of the writer for which the reference is made in the footnote.[4]

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3) A. Sieberg, "Erdbebenkunde," Kap. 14, Jena, 1923. See also A. Sieberg u. R. Lais, "Das mitteleuropäische Erdbeben von 16 Nov. 1911," *Veröff. Reichsanst. f. Erdb. fors. i. Jena*, Heft 4.

4) S. Günther, "Geophysik," I, (Stuttgart 1897), 477; Corn. Tacitus's Annali cited regarding the luminous phenomena observed on the occasion of an earthquake in Achäian cities in 373 B.C., which is the earliest example; literatures on allied matters found in citate

Examining these numerous materials it will be seen that the phenomena recorded are of extremely variegated features but may be conveniently classified into a number of types, which are represented on different occassions in different nuances of forms and combinations. I. Galli classified:[5] (I) indefinite instantaneous illumination, (II) well-defined and mobile luminous mass, (III) bright flame and emanation and (IV) phosphorescence of sky and clouds. The class (I) was subdivided into (a) lightning (lampi e bagliori), (b) sprinkles (sprazzi luminosi) and (c) streamer (strisce luminosi sottili). The class (II) contains (d) fire-ball (globo di fuoco) (e) fire-column (colonna di fuoco), (f) beam of fire (trave di fuoco) and (g) luminous funnel (tromba luminosa). The class (III) including those phenomena which appear from the earth and last for a sensible duration of time, is subdivided as (h) flame (fiamme), (i) little flame (fiamelle) (j) spark (scintille numerose) and (k) luminous vapour (vapori luminosi). Lastly, the class (IV) is divided into (l) diffused light in the sky (luce diffusa nell'aria) and (m) luminous cloud (nube luminosa). These classifications seem to cover almost all the examples in the occidental literatures above cited as well as in our collection of the Japanese documents and testimonies. Though such a classification is liable to much ambiguity, as the meaning of the same words used by different witnesses may have more or less different contents, we will sometimes conveniently refer to this classification in the following description of Japanese examples.

Examples in Japan.[6]

Above forty examples of documents concerning the luminous phenomena observed in connection with severe earthquakes dated up to the

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at the end of Chap. 4. Urbanitzsky, "Die Elektrizität des Himmels u. d. Erde," (1888), 358. R. Hoernes, "Erdbebenkunde," (1893), 113–116. E. Hennig, "Erdbebenkunde," (1909), 111–113. J. Milne, "Seismology," 330. K. Futterer, "Das Erdbeben vom 22 Jan. 1896," Karlsruhe 1896, 32. "On Earthquake of Dec. 17, 1896," *Symons's Met. Mag.*, (1897), 183. W. Gaw, "Atmospheric Phenomena during the Chili Earthquake," *Symons's Met. Mag.*, (1906), 228. A. Sieberg u. R. Lais, *loc. cit.* Myron L. Fuller, "The New Madrid Earthquake," *Bull. U.S. Geol. Surv.*, 494 (1912), 46. Baily Willis, "Earthquake Condition in Chile," 30. I. Galli, *loc. cit.* It is said that luminous phenomena were also observed on the occasions of San Fransisco Earthquake of 1906 and the recent Italian Earthquake of 1930, though the reliable documents are not at hand. For an example of Chinese earthquake, we may cite 童振藻, 雲南地震考 (1926), in which it is stated that on the occassion of Yunnan earthquake of March 1925, immediately before each of the severe shocks sulphurous smell was felt and fiery light discovered in the sky which moved from N to S.

5) The numbering of the classes and the alphabetical denominations are not given in Galli's paper, but introduced here for the sake of convenience.

6) Most of these examples are cited from "Dainihon-Disin-Siryô", some from Musya's collection and the rest from other miscellaneous sources

beginning of Meidi Era (1868), are found in Musya's collection, of which about twenty refer to the Ansei Earthquakes (1854 and 1855). The earliest record in Sandai-Ziturokn (三代實錄) states that on the occasion of the severe earthquake in Mutu, N. Japan, in 869 A. D., "streaming light was seen as if it was daytime" and its intensity seems to have shown some sensible fluctuation (流光如晝隱映). The phraseology suggests that the luminosity was something unusual and different from that of lightning, perhaps belonging to Galli's class I or IV. In Kamakura Earthquake of 1257, bluish flames were seen to emerge from the fissures opened on the ground[7]. This belongs apparently to Galli's class III. In the case of an earthquake in Suruga and Tôtômi 1589, the luminosity observed from a distant quarter is expressedly stated as "not like lightning" and also "whole sky illuminated." Flying luminous bodies are mentioned in connection with two local earthquakes in Yedo in 1630 and 1672; as these occurred in winter, the connection with thunderstorm is improbable. In the case of 1672, a fire-ball resembling paper-lantern is mentioned which was seen flying through the sky towards E. In the case of Tosa Earthquake of 1698, a number of fire-balls like wheel were seen flying in different directions. In the case of Great Genroku Earthquake of 31 Dec., 1703, in Tôkaidô, luminous "bodies" and "air" were frequently seen in the nights preceding the day of the severest shock[8] and, afterwards, a kind of luminosity like the sheet-lightning continued to be seen for about twenty days, even when there was no cloud to be seen. This earthquake occurred also in the season when the thunderstorms are extremely rare. It is needless to say that there existed no electric transmission lines. Galli's "fiamme" is again met with in the case of Sandyô Earthquake of 1828 and Sinano Earthquake of 1847. In the latter case, "lampi e bagliori" are also reported. One of the records states: "Under the dark sky, a fiery cloud appeared in the direction of Mt. Iduna. It was seen to make a whirling motion[9] and then disappeared. Immediately afterward, a roaring sound was heard, followed by severe earthquakes." Again, "the luminosity accompanying the enormous land-slide of Mt. Iwakura was of so strong intensity that it was as bright as daylight to every corner of houses." At the time of earthquake of 19 Aug. 1830 in Kyôto and its vicinity, it is stated that in the night preceding to the earthquake luminous phenomena were seen in the whole sky and some kinds of luminosity were emitted also from the ground which were so bright as to be compared with daylight. The people were wondering at the unusual phenomena until the severe earthquake was experienced on the next day. In the case of Ansei earthquake of Nov., 1855, different forms of luminous phenomena[10] were reported and, in this case also, the season was near the minimum of thunderstorm frequency.

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[7] *Cf.* GALLI, N. 128: "……par les fentes que l'on me montrait (fentes causèes par le tremblement de terre et qui n'existaient pas auparavant) on avait vu sortir du feu"; and many others.

[8] See foot-note, p. 235.

[9] *Cf.* resolving motion mentioned in p. 240.

As for the examples recorded after the Restoration of Meidi, we may cite the following.

1889, July 28, Kumamoto Earthquake: According to "Kumamoto Meidi Sinsai Nikki", a fearful lightning flash (or flashes ?) was seen towards E immediately before the arrival of shocks. Afterwards, lightnings were observed towards W till the next dawn. In the previous (?)

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10) We may cite a few examples from MUSYA's collections: "At the time of the earthquake, a luminosity resembling lightning was seen towards E which disappeared after a short time". "Before the noon, something like a vertical rainbow was seen towards SE". "An witness, who were afishing off Sinagawa, saw flashes like lightnings towards Yedo (Tôkyô) at three or four places." "A party of 19 persons went to sea on the eve of the earthquake. Before the time of the shock a sudden luminosity was seen towards NE, which was so bright that the coloured patterns of their clothes could be well discerned. Soon afterwards, a horrible roaring sound was heard from underneath the sea, which gave them an impression as if a mass of gravels were impinging upon the bottom of the boat. At the same time a mass of flame went flying through the sky accompanied with sounds." "A person in Ikenohata, Sitaya, observed at the time of the shocks a luminosity towards NNW which was quite unlike a lighting. "At Yosiwara, fissures were formed on the ground, from which a beam of white 'air' (luminosity) emerged. It moved aslant toward Asakusa Temple." "A man in Usigome was surprised to see the window illuminated. Towards S he saw a slender beam of ruddy light which was bent like the handle of a kettle. He was wondering at the phenomenon when the sudden shaking of the ground was felt." It seems that the luminosity preceded the first shock; moreover, the curved beam of light mentioned resembles to a similar phenomenon observed by Mr. HATTORI on the occasion of Tanzawa-yama Earthquake of Jan. 15, 1924, cited later. "A traveller on his way through Koisikaw at midnight saw some 'dark air containing bluish luminosity' which moved rapidly from NE to S accompanied with a sound like strong gusts of wind. Soon afterwards, the earthquake shock was felt." There are several witnesses who state to have seen some dark object flying through the sky which is rarely mentioned on the other occasions. It is possible that a physiological effect might here be concerned. "In the night of the earthquake, fire was seen to be emitted from the ground somewhere near Gyôtoku, Simôsa. On approaching the spot where the flame seemed to emerge, nothing could be found, but the similar fire was seen in front again at some distance from thence."

night, a fire-column had been seen to pierce the cloud, while it was raining. In the night of the earthquake which occurred at about 12h, the sky was at first clear with abundunt shooting stars and afterwards it begun to rain. The season was near the maximum of thunderstorm frequency and we are not in possession of the weather chart of that time so that it is difficult to tell whether the light seen was not the usual lightning.

1891, Oct. 28, Nôbi Earthquake: In the preceding night lightnings were seen towards W from the village Miyake. Frequent lightnings were also seen at Tusima-Mati.

1896, June. 15, Sanriku Earthquake with tunamis: Fishermen 30–40 ri off the coast saw something like burning fire and after a short time heard a sound like cannonading towards the land.

1909, Aug. 14, Kônô or Anegawa Earthquake: According to Prof. Koto's report, the western slope of Mt. Ibuki slided down and some luminous phenomena observed.

1917, May 18, Earthquake in Suruga and its vicinity: Fire-column was seen in the mountain north of Siduoka.

1918, Sept. 11, Oomati Earthquake: According to Prof. S. Tsuboi's report, at the time of the second severe shock, a kind of luminosity was seen in the directions of mountains in Hida and Sinano to W. of Ikeda-Mati.

1923, Sept. 1, Kwantô Earthquake: Fishermen of Awa saw several fire-column appearing in (?) the sea in a part of the Sagami Bay near the mouth of the Bay of Tôkyô, on 1 (or 2) Sept. A staff-member of the Central Meteorological Observatory observed a kind of stationary fire-ball in the sky of Tokyo. A woman in Hukagawa saw a flashing light on the sea in the morning, i.e. before the earthquake, of Sept. 1. A student observed unusual luminous phenomena towards the direction of Bôsyû in the night of Sept. 2 (?).

1924, Jan. 15, earthquake in Tanzawa-yama district: A luminosity was seen in Yokosuka at the time of shocks. Such was also seen from C.M.O., Tôkyô, towards W. Fishermen off the coast of Kôdu saw a strong light on the southern slope of Mt. Tanzawa. Mr. K. Hattori, Assistant in Aeron. Res. Inst., who was dwelling at that time in Terazima-mati on the E-side of R. Sumida, was awakened by the first shocks and hurried out of door, when he happened to observe a pillar of fire over the roof of a house towards N. It was slightly bent with its concave side to the right and its upper end merged into a diffuse sheet of light attaining a considerable altitude. The colour of the light was pale white. The sky was clear. Two persons saw the same phenomenon. It is interesting to notice that this latter example bears a remarkable similarity with that depicted in Fig. 58 of Sieberg's book cited.[11]

1925, May 23, Tazima Earthquake: At the time of one of the severest after-shocks which occurred during the night, Mrs. Yamamoto of Hukutiyama observed a luminous ball, reminding her of a foot-ball, in the sky in the direction opposite to Kinosaki, i.e. the epicentral region. It moved rapidly from NE to S like a shooting star and disappeared somewhere.

1927, March 7, Oku-Tango Earthquake: Mr. S. Sawada of Hirakata-Mati, observed at Huse-Mati a luminosity towards E which he supposed to be due to sparking of an electric transmission line in the neighbourhood. Mr. K. Saito of Kyôto was in an electric car running from Kôbe to Osaka at the time of earthquake. He observed an unusual luminosity of night sky towards Mts. Muko and Rokkô, not quite unlike a distant fire-brand, but of quite unusual colour. Fishermen of Taiza who were fishing off the mouth of R. Asamo observed a luminosity above the sea towards E, which was more reddish in hue than the usual lightning flash, and paler compared with a candle light.

1928, May 21, a local earthquake in the NE part of the Tokyo Bay: Mr. Hattori, Aeron. Res. Inst., observed a diffuse illumination of sky a few second after the first severe shock. The flashes which seemed to be of longer duration than that of a lightning, were repeated two or three times; they also seemed to occur nearly simultaneously with the maxima of earth's disturbances. Dr. S. Yamaguti of our Institute observed a flickering luminosity in the southern sky which continued during the shocks and abated with it. The colour was like that of an electric spark and the luminosity seemed to reach an alittude of about 10°.

1930, Dec. 20, a local earthquake in Hirosima Prefecture: Mr. B. Takeda of Syôbara-Mati states that several persons observed some luminous phenomena towards N at the time of the severest shocks as well as during some of the aftershocks. It is stated by several witnesses that the northern sky was illuminated by a ruddy light as in the case of a fire-brand. Some one is said to have seen a fire-ball. Elecric light was extinguished at the time of earthquake. Mr. K. Nozaka, the Master of Syôbara Common School, reports that a fire-ball was seen from the school towards NNW, which moved upward and vanished, followed by a luminosity in all directions. A member of the Village Office in Syôbara observed a purple flash of radiating light towards WNW. Mr. N. Emura of Kimita School saw white light of indefinite extention towards SE, NW and E respectively. The report from Kimita Village Office states that immediately after the severe shock of 20 Dec., an illumination of the sky towards NE was seen resembling a distant fire and the similar phenomenon was also seen in the night of 21st. in two directions N and S. Lastly, Mr. M. Hara of Kutikita-Mura, Hiba District, observed immediately after the shock a beam of light like an inverted brush or a signal fire rising upward and illuminating the clouds with a hue similar to a fire-brand. The light gradually faded upwards. Besides, a faint general illumination was seen in the lower sky just above the mountains, first in SW direction and then in SE and N.

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[11] A similar kind of curved fire-column was seen at the time of Ansei Earthquake (see foot-note p. 229); another, probably of the same class, was seen in the present case of Idu Earthquake (see p. 232).

In most of the above examples, no strong evidence could be brought forth against the criticism which may be applied as regards the suspicions whether they were not due to lightning, electric short-circuiting etc. In this respect the recent Idu Earthquake of Nov. 26, 1931, may be cited as an unique case in which the abundance in number of testimonies far surpassed the total sum of all the above cited and the detailed features of evidences allows no room for suspicion as to the physical reality of the phenomena as an immediate appendage of earthquake shocks.

Examples from Idu Earthquake of 1930.

Immediately after the earthquake of Nov. 26, 1930 in Idu district, Mr. K. Musya sent a circular inquiring after detailed informations regarding any form of luminosity observed in connection with the earthquake, adressed chiefly to the masters of the boys' and girls' middle schools in the neighbouring prefectures. The data accumulated in this way amount to 1168 in number.[12] Mr. K. Musya made a thorough study of these data and already published a summary of his results of investigations in the preceding number of this Bulletin.[13] The present author also examined these data which was kindly placed at his disposal, and confirmed Musya's results in the essential points. Besides, the author was able to obtain about 15 data from the sides of persons more or less trained in scientific observations. Besides, about twenty other reports were also gathered from the side of laymen witnesses among the inhabitants of Tokyo as well as of different localities in Sagami and Idu. Moreover, another set of valuable data was obtained by the courtesy of the Central Fire-Brigade Station of Tôkyô which consists of the testimonies of the firemen who were in charge of night watch on the watching towers of different local fire-brigade stations situated in different quarters of the city. The latter data are especially valuable, as the witnesses were awake before the arrival of the earthquake shocks and they could be expected to be especially alert to any trace of unusual luminous phenomena of night. These additional data taken altogether bring, however, nothing essentially new to the summary given by Musya.

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[12] On examining these data from the school boys and girls, it was noticed that their testimonies are neither always original nor independent from each other, being apparently influenced by the effect of mutual conversations and inquiries, so that the coincidence of testimonies is not necessarily the proof of their truth.

[13] In the following his paper will be as K.M.

With regards to all these testimonies of witnesses, it must be always kept in mind that people are naturally alive to all kinds of phenomena observed at the time of a severe earthquake and apt to regard them as something connected with the catastrophal occurrence, while they forget to consider that the same phenomena are frequently observed on many other occasions not at all connected with earthquake. On the other hand, we learn from the results of investigations by psychologists in what a ludicrous manner the testimonies of people, otherwise quite normal in mentality, may appear distorted when compared with the bare truth. These points taken into due account a sufficiently numerous independent testimonies may still give at least a general outlines of what really happened.

In the following will be given a review of the essential features of the phenomena with some discussions.

(*1*) *The extent of localities where the phenomena were observed:*

The phenomena were seen as far as 80 km. to E, 110 km. to NE and 70 km. to W of the epicentral region. The geographical distribution of the observers shows a peculiarity which seems to be due to different factors such as the density of population and the intensity of shocks felt. Abundance of data in the city and suburb of Tôkyô may naturally be explained by the former factor. The same factor seems to explain the decided superiority in number of data on the western side of R. Sagami compared with the eastern side. Extreme scantiness of the reports from the Tama Terrace, situated between Tôkyô and Sagami River Plain, may probably be due to both the causes above mentioned. The observers in Bôsô Peninsula are confined within a zone with a breadth of 5–10 km. along the coast of the Bay of Tôkyô, extending to the mouth of R. Yôrô to N and to Tateyama to S. The western-most point of observation was at Yaidu in Siduoka Prefecture and the southern-most at the vicinity of Simoda, Idu. No report was obtained from the mountainous districts to N of the line connecting Mt. Ooyama with Hatano, Yamakita and Gotenba.

(2) *The time of observation:*

The greatest majority of witnesses were those who were awakened by the severe shocks, and hurried to open the door and get out. There are a few who became aware of the phenomena by looking out through glass windows immeditately after awakening. A watch-man who was in charge on the top of the watch-tower of Sibaura Branch Fire-Brigade Station, Minami-Hamatyô 18, states that he has observed a flash of light towards S about 10 minutes[14] before the shocks, and afterward four or five spark-like flashes during the earthquake. He also states that the peculiarity of the time relation drew his special notice. Another report due to Mr. T. Makino of Itô is worth of special notice, which states that a number of fishermen who were about to set their boat afloat in the evening previous to the earthquake observed a spherical luminous body to W of Mt. Amagi which moved towards NW with considerable speed. This fire-ball was seen at about 4 o'clock pm. of 25th. while the severe shock occurred at 4 h 3 m in the next morning.[15] Three other examples of unusual light phenomena seen before the midnight of 25th. in different places near the epicentral district are given in Musya's paper, K.M. p. 179.

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14) The examples abunduntly cited in GALLI's collection as well as in ours in which the shocks were felt immediately after the luminosity, may be explained by the time required by the earthquake waves to traverse the distance from the origin to the observer. The time here stated seems to be too long. It is, however, not clear whether the luminosity began to appear so early, or some kind of illusion was committed.

15) This testimony of the fisherman reminds us of an article in NANKEI TATIBANA'S "Tôyûki" (橘南谿, 東遊記 A Journey to Eastern Countries) in which a luminous phenomenon is described as a foreboding of a dreadful landslide. The fishermen of Nadati, Etigo, who were afishing off the coast observed a remarkable ruddy glow towards the land which they considered to be due to a great conflagration. On landing and returning to their native village they were surprised to found that nothing unusual has happened in the vicinity. On the next day, however, a landslide of enormous scale took place in the same locality and buried the unfortunate fishermen who could not understand the fearful omen of the previous night. It may be supposed that the landslide had already been commenced preceding the final catastroph, somewhere in remote regions devoid of popula-

In this connection, a very singular fact may be recorded that Mr. Mukuhira in Tango, an amateur in "earthquake prediction" sent in the afternoon of 25th. a telegram adressed to the Director of the Science College of the Imperial Kyôto University giving the warning of an earthquake to be expected in Idu districts at about 4 o'clock next morning, which turned out to be true. The photogram of the telegram was reproduced in *Oosaka Mainiti* of 28th. Nov. According to the newspaper he based his prediction on the observation of a certain rainbow-like phenomenon which was seen in the morning of 25th. Though we are unable to trace any scientific basis in his way of prediction, the coincidence is nevertheless quite remarkable. It must be remarked, however, that vague anticipations of a severe earthquake to occur in Idu was prevalent among the laymen interested, on account of the frequent repetition of swarm earthquake in that region since the spring of the year. What is remarkable is that the exact time of occurrence was "predicted" and moreover that he was so convinced and determined as to send the telegram stating this very time. From the present status of our science we cannot but attribute this coincidence to a rare chance, but it is too rare and interesting to be entirely discarded from the literatures of earthquake phenomena, especially because it is connected with some luminous phenomena in the sky, though his "rainbow" was seen in the daytime and belongs to none of Galli's classification above cited.[16]

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tion. In the present example of Idu Earthquake above cited, it may also be conjectured that somewhere in the mountainous district of the epicentral zone a conspicuous sliding has happened on the eve of the day of the earthquake though there is no positive evidence available. At any rate it is desirable in view of such a possibility to pay due attention to any luminous phenomenon reported to have been observed preceding a severe earthquake and not to cast away such data too hastily as a priori improbable. In this respect, cf. for example, GALLI, No. 72, in which different luminous phenomena are given which were seen in the evening before the severe shocks.

16) According to the newspaper "*Tôkyô Asahi*" of June 8, a telegram from London states that an unusual luminous phenomenon was observed in London in the night two days before the earthquake of 7th. June. A detailed description of the phenomena, if real, is desirable, whatever may be their actual causes. Here, we may add a case of an apparent prediction of the earthquake of Genroku 16 (1703 Dec. 31) by SUKEZAEMON SIBUKAWA, the Astronomer of that age in service of Syôgun. It is stated in a document recorded in "Dainihon-Disin-Siryô" that on the eve of the great earthquake, he gave a positive warning to the officers in the residence of Syôgun to the effect that a severe thunderstorm or earthquake is expected in the course of that night. It is also stated that he was constantly in the habit of watching the night sky, as is natural for an astronomer. It is worthy of notice that he apparently treated thunderstorms and earthquakes under the common category (cf. ARISTOTELES: Meteororum, lib. II, cap. 9). This suggests that his premonition

(3) *Varieties of phenomena observed.*

Almost all the varieties of phenomena classified by Galli were represented in the present occasion (cf. K. M. pp. 183–197). Most numerous examples seem to belong to Galli's (Ia) lampi e bagliori, i.e. the sky was illuminated in a manner not unlike the usual sheet-lightning. The greatest majority of the observers remote from the epicentral region describe the phenomena as such. Most witnesses in Tôkyô observed one of the flashes immediately after the first shock which was followed by three or four similar flashes with irregular intervals of few seconds, varying from 1 sec. to 10 sec. according to the estimation by a number of physicists. Almost all agree in saying that the duration of a single flash was decidedly longer than that of a usual lightning. The unusual duration has also attracted the attention of some laymen who positively emphacize this point in their reports. On the other hand, some state that a single flash was steady and showed no fluctuation, while other speak to the contrary. This latter point may depend upon some physiological effect so that it is not easy to decide which was right. Or, the different descriptions may refer to different phenomena. As to the extent of the part of sky illuminated, there are some testimonies which state that it reached 20–30 degrees from the horizon, but it must be kept in mind that probably no one would care to look towards the zenith in such an occasion. The directions in which this kind of phenomena was observed are extremely various and contradicting with each other even among the observers in the same locality. It seems to depend on the direction at which the observer happened to be facing at the time of the occurrence of flash. Thus, it will depend on the direction towards which the window or door opens, and also on the topographical conditions, such as the slope of the land as well as the vicinity of sea. There will also come into play a probable psychological moment of the inhabitants of suburban districts to look involuntarily towards the city centre in the case of occurrences arousing general alarm. It is, therefore, hopeless to decide upon the position of the source of these "lampi" from the data at

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was based on some luminous phenomena not unlike lightnings. As already mentioned, it is recorded also in other documents regarding this very earthquake that luminous phenomena were frequently observed in the night (or nights?) preceding the catastroph, notwithstanding that the season was just near the minimum of thunderstorm frequency. All these examples as such are certainly not able to stand the criticism of scientists, but it will not be legitimate to cast away these cases on account of mere prejudical reasoning, especially when there are more than one physical possibility of premonitory phenomena as are discussed in the present paper.

hand. It will not be far from the truth to assume that in Tôkyô and its western suburb almost the entire sky was illuminated at the moment of flash.

On the other hand, the distribution of clouds at that time must be taken into consideration with regard to the above question. Mr. Kita, Student of Physics, reported from Takinogawa Observatory that the sky was generally clear with KC 3 towards SE–SW at 4h 5 m. Another reliable testimony by Dr. Wadati who observed about four flashes at his dwelling in the western suburb, states that the sky towards S was overcast with greyish stratified clouds and the light seemed to be emitted from one of the strata. According to the data kindly furnished by Mr. Saki of C. M. O., the cloudiness at 2h am. was: Numadu 10, Yokohama 4, Iida 0, Kôhu 1, Kumagaya 0; at 6 am., however, a remarkable change had occurred, i.e. it was 10 for Hamamatu, Numadu, Nagatoro̤, Tigasaki, Yokosuka, Yokohama, Misima, Tôkyô, Mera, Tateyama, Hakoneyama, Kumagaya, Oome, Tokorozawa and Titibu, 9 for Katuura, Tyôsi, Mito, 8 for Tukubasan, and 6 for Maebasi. Mr. Kita went out of door again at 4h 10 m and was surprised to notice the rapid change in cloudiness within so short a time, as the cloudiness now attained about 8 and beside KC in the sourthern sky there was seen a *thin sheet of SC* which was moving towards SW with the speed 5. On more flash was observed at that time which was decidedly longer in duration than ordinary lightning.

Looking at the map constructed by Mr. Musya giving the statistical distribution of the directions of light observed, a tendency may be observed that a large number of the data point either towards the Bay of Tôkyô or to the Sagami-gawa Plain. As the hour was just at the minimum of daily temperature, it may be suspected that there was some component of ascending air current above the bay and the river plain, resulting in somewhat earlier cloud formation in these region compared with the others.

A phenomenon reminding us of auroral streamers diverging from a point on horizon is described accompanied with a sketch, by a witness at Minato-mati in Awa on the eastern side of the Bay of Tôkyô (see K. M. p. 187, No. 73). The radiant point is identified by reference to the profile of hills in the background of the sketch and may be traced to the direction of the epicentral region. Similar sketches are given by others.

Beams (trave) and columns (colonna) were also seen at different places with different forms, directions and modes of motion (cf. K. M., pp. 190–

194). Several observers compare the phenomena to the beam of a search light. Fire-balls (globo di fuoco) are also repeatedly mentioned (K. M. pp. 195, 196–197). It may be noticed that the ball-form and also the funnel-or trampet-form (tromba, K.M. p. 195) of luminosity were mostly seen near the epicentral districts. A witness in Odawara observed a fire-column, one (upper ?) end of which was bent towards Idu Peninsula. This reminds us of what was seen by Mr. Hattori on the occasion of Tanzawa-yama Earthquake (p. 230) of 1924 and also of another similar example of Ansei Earthquake (p. 229 foot-note).

Highly variegated forms of luminosity which may belong to Galli's (IV m) " nube luminosa " (K. M. pp. 195–196, also pp. 188) are abundantly reported, often apparently with fantastic exaggerations. Some positively state that detached clouds were illuminated. Mr. Musya is in possession of an oil painting by an observer in Hibusuma-Mura, which may be cited as an example of this same class. Another remarkable example probably belonging to this class is reported by an observer at Hongô, a few km. to N of Simoda in Idu, who observed three blinding flashes of light towards S, i.e. in the direction opposite to that of the epicentral region. He gives a well depicted pen-drawing sketch, according to which it seems that the luminosity was concentrated to a portion of the sky with considerable altitude, giving the impression of a luminous cloud. It is stated that the luminosity was so strong that different objects at a distance of about 250 m. could be well discerned. Another observer in Otiai, near the former place, saw " a funnel-shaped light (sic) resembling a beam of search-light " also to S.

In the districts not far from the epicentral region, the descriptions of the phenomena assume more or less definite form instead of an indefinite flashing of sky. One of the class of phenomena is represented by the personal observation of Dr. S. Nasu of our Institute who happened to be staying in Itô at the time of earthquake. Immediately after the severe shock he observed a ruddy glow above the profile of mountain ridges towards NW and WSW, which remained for a few minute.[17] Mr. Makino, the observer in charge of the seismograph in that town, observed the same phenomena. He had once happened to observe somewhat similar phenomena on the occasion of a great fire in Numadu (27 km.

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[17] *Cf.* GALLI No. 121: " Si videro delle fiammelle sortire dal suolo, e queste durarono per qualche minuto dopo cessato il terremoto." " Sopra questo monte poco dopo il terremoto fu vista una luce rossastra per brevissima durata di tempo, che illumina il paese di Pioraco e sembrava uscire dal medesimo monte."

NW). "Comparing the two phenomena the glow due to the fire-brand was characterized by frequent fluctuations of intensity, whereas the glow seen in the present case of the earthquake was kept nearly steady in luminosity showing no sensible flickering." The colour of the light was dark red with orange tint, according to a colour match made by Mr. Watanabe of Itô Common School. It seems rather strange that the flashing light was not stated by these witnesses. Another example of the same kind of glow is given by Prof. Saem. Nakamura in Vol. 3, No. 2 of "Disin" with a coloured sketch by the observer Mr. S. Nisimura in Ubako, Hakone. In the same Plate is shown a similar sketch by Dr. Nasu of his personal observation in Itô above mentioned.

A very vivid description of the most remarkable phenomena observed at Hakone-Mati which was one of the most severely shaken places, is given by one of Musya's collection which is due to Mr. Isiuti, his son and others. His son who hurried out of door and was clinging to a tree to keep his equilibrium observed a flashing luminosity on the slope on the NE side of the Lake ranging from Komagadake (4 km. N) to Kami-yama (5 km. N) now in a spot and then in another, thus successively in different places. The intensity of light was such that trees and clouds illuminated by it could be sharply discerned. The sources of light seemed to be of a round shape sometimes large and sometimes small. According to Mr. Musya there is no electric transmission line passing this side of the lake. On the other hand, numerous land-slides took place on the slopes of mountains facing to the Lake. Again, according to the testimonies of the others the following details are given.

"Luminosities were seen on the mountains in different directions. The brightest one was at a spot near the wireless tower (1·5 km. SW). They were seen towards Kurakake (1·5 km. S) as well as on the mountains in SW. The colour of the light was limpid blue."

"The garden and the pond of the neighbouring Hakone Hotel were clearly seen on account of the illumination so that the observer was not aware of the fact that the electric light was extinguished."

"The illumination was so strong that the *broken electric transmission line* lying on the ground was clearly seen and the witness took care not to touch it on his way. The brightness was similar to that at the time of full moon. Everything in the neghbourhood could be well discerned."

"While a staff-member of the wireless station was hurrying to Mr. Isiuti's house, he could make his way without the aid of a lantern," which is apparently needed in a dark night. "He became aware of the darkness only when hails began to fall, about 40 minutes after the earthquake. Up to that time, he could attend to his affairs without the aid of a candle."[18]

"The light appeared to be emitted from below, during the earthquake. It was after a considerable time that it was seen in higher quarter."

"When the earthquake was at its height, *a straight row of round masses of light*[19] was seen towards the Manpukuzi Temple (SW). Each of these luminous bodies was seen to be in revolving motion. The brightness was considerable. Their heights seemed to be equal to the top of poles of transmission lines."

"Formerly, it had once happened that a crow caused the sparking of a transmission line. A loud noise was heard at that time. In the pressent occasion, however, no unusual sound was heard."

There are some reports regarding the observations made off the coast of Idu, which are interesting in many respects. According to Mr. R. Nisizima of Aziro, a number of fishermen afishing off the coast near the island Hasima at the time of the earthquake, observed a fearful display of luminous phenomena all along the mountainous districts of the epicentral zone. According to the manuscript of a fisherman, as reported from Kawana Common School, the phenomena were observed from the beginning on a boat off the island Hasima. The light first appeared above Mt. Hakone and it was seen to be propagated southwards, towards Mt. Amagi.[20] Then it was reversed in its direction of propagation and went back towards Mt. Hakone. The light which was white in colour was seen only near the ground. When he was wondering at the unusual

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18) *Cf.* GALLI, No. 54: "Poco prima delle furiosissime scosse . . . quelli, que avevano gli scuri o sportelli delle fenestre aperti, veddero nella loro camera tal chiarore, che per non breve spazio di tempo poterono distinguere tutti gli oggetti anchorchè piccoli, che si presentavano alla loro vista, in modo che qualcheduno credette che fosse già cominciato il giorno." ". . . un grandissimo chiarore, col quale vedeva distintamente tutto il paese, e che tale si mantenne nel tempo ch'egli impiegò a percorrere lo spazio di 20 passi, dopo del quale senti egli tremare la terra."

19) *Cf.* GALLI, No. 59: "osservato di sera venir fuora certe fiammette della grandezza e similitudine di quelle di una picciola candela, situate una presso d'altra quasi in eguale distanza e direzione, formando una linea retta.

20) *Cf.* GALLI, No. 141: ". . . si vedere di notte delle striscie di fuoco attraversare il M. Nerone in senso orizzontale, fenomeno che si ripetè poche ore prima della scossa successiva . . ." Also No. 127, last paragraph. Again, No. 146: an observation, made on sea, of "una luce come un faro luminoso, che lentamente procedeva da Sud-Est verso Nord-West, lasciando dietro una gran fascia di luce donde cadeva una pioggia di scintille." The latter description reminds us of the description of land-slide in Siroyama, Oohito (p. 241).

sight, sudden shaking of the boat was felt, which he attributed to an earthquake. While talking with the others about the unusual nature of the shock felt, they saw fiery displays at three spots of the land, which he considered to be due to some volcanic eruptions accompanied by the earthquake. On landing, he found that there was no eruption, but a firebrand was caused by the earthquake." As a matter of fact, fire broke out in the town of Itô after the earthquake by which a number of houses were destroyed. Another conflagration seems to have taken place in Kôdu which was however due to other cause than the earthquake, and had been almost extinguished at the time of the earthquake shocks. Again, a fisherman of Siduura on the western coast of Idu is said to have observed on sea a large fire-ball starting from Mt. Wasidu and moving towards S.

There are a few reports regarding the light observed in apparent connection with land-slides, inspite of the fact that the latter were quite numerous in the epicentral region. According to the newspaper, "*Misima Asahi Sinbun*," a minor land-slide at Siroyama in front of Oohito Station was accompanied by a display of light similar to that of a pyrotechnic show initating a waterfall; it is stated that light was produced by the mass of small stones falling down along the rocky slopes of the mountain. In Mr. K. Hasimoto's letter to Mr. Musya, the testimony of a newspaper-saler is given who saw a luminosity at the moment when a land-slide took place at a distance of about one km. and he attributes the light to the heat produced as the effect of sliding. Another example is given by the testimony obtained by Mr. Musya from a chauffeur at Yugasima, who states that a large fire-column appeared at the time of great land-slide at Kadiyama. The same fact was also stated by another witness in Nakaômi.

The row of round luminous bodies observed by the family of Mr. Isiuti above mentioned (p. 240) may also be connected with land-slides which took place in numerous spots on the slopes facing the Lake.

On the other hand, according to the statement of a witness in Kadiyama recorded by Mr. Musya, no one in the immediate neighbourhood of that place seems to have observed the luminous phenomena at the time of the great land-slide, while those at distant places saw such phenomena towards the direction of Kadiyama.

It is rather remarkable that among the thousand data accumulated there are few reliable testimony of those witnesses who happened to observe remarkable electric sparks actually caused by breaking or short-circuiting of electric transmissoin lines, though there are superfluous number of reports stating that the light was much *alike* the flash produced by such a sparking. It is said that a man at Misaki actually saw a broken electric line sparking at the ground. Another reporter from Matuda near Kôdu writes to the effect that the luminosity observed was due to the short-circuiting, but it is not clear whether he actually observed such thing. A similar report from Mera Observatory is equally not quite convincing. On the other hand, there are some reports stating that the light was seen towards the direction at which there is passing no transmission line. As a matter of fact, in the circular send out asking for informations there was no special item inquiring after such accidences, so that it might be supposed that the report regarding this point was naturally eliminated.

There are, on the other hand, a few reports stating the conditions of the electric lighting at the time of earthquake. In a village named Seya (瀬谷), Kamakura-Gôri, a transformer was seen to be sparking and immediately afterwards, the electric light went out. In Hudisawa and Kugenuma, the electric light dimmed awhile at the time of shock and recovered after a short time. Prof. N. Mononobe who was awaken and reading in his residence in Azabu, Tôkyô, noticed a momentary dimming of light. The light soon recovered and then the preliminary tremor of the earthquake was felt.

The author made an inquiry at the Department of Communication with the purpose of ascertaining whether any powerful trasmission line was seriously affected by the earthquake. No positive evidence could however been obtained up to this day. Perhaps it is not practicable to confirm this point after the lapse of several months.

(4) *Colour and intensity of light observed.*

The colour of the light observed is reported by a great majority of of observers, in the case of flashing "lampi", as pale blue, white, or as similar to that of electric sparking or lightning. There are also a large number of witnesses who state positively that the light was decidedly of reddish or orange colour compared wiih the usual lightnings or sparks. In the case of that kind of glow which was observed over the mountain ridges the ruddy colour predominates. Sieberg and Lais emphacized the reddish tint of the light observed on the occasion of the earthquake as one of its characteristics. The present examples seem to confirm their opinion.

It is well known that a faint light is perceived mainly by the peripheral region of retina which is devoid of colour sense. The colour of lightnings or sparks usually described as blue, pale blue, greenish grey, etc. seems to be really connected with this colourless luminosity.

In this connection it may be added that an electric spark may sometimes show an apparent propagation of luminosity along its track due to an optical illusion,[21] while the actual discharge phenomena is completed within a very short interval of time, 10^{-6} sec. say, and no such propagation can be detected by means of ordinary rotating mirror or the like. Some of the descriptions regarding the apparent propagation of luminosity *along* the track or beam of light, may be due to this kind of illusion.

As to the intensity of luminosity observed at distant quarters, it is stated by a number of reliable witnesses in Tôkyô that different objectss in the room illuminated through glass windows could be discerned (cf. foot-note 18). At that time, the eyes of the most observers were completely accustomed to darkness, so that the light might have been quite weak, though it is difficult to give any reliable quantitative estimation. Assuming, for example, that the illumination of a wall in Tokyo was of the same degree as that due to a single candle placed at a distance of 10 m. and that the source of the luminosity was in Idu at 100 km. distance the candle power of the source will amount to $10.^8$ According to the estimation of an expert in naval engineering, the total candle power of a certain squadron in full display of festival illumination amounts to about 3.10^7 CP. If a light source of these orders of magnitude were placed in an elevated mountain region with comparatively clear atmosphere, it may probably produce a considerable illumination of sky even at 100 km. distance, especially when there was a suitable distribution of clouds to catch and reflect the light. The question is how a source of light of such an enormous candle power could be produced by earthquake.

(5) *Probable and possible causes of luminosity accompanying earthquake.*

From the superfluous number of testimonies, among which we may cite those given by most reliable scientists, it will be beyond any doubt that the luminous phenomena reported are neither entirely due to the illusion of untrained minds struck by the earthquake shocks, nor due to some purely physiological effects, though much distortion or exaggeration might have slipped into the descriptions of the phenomena especially in the case of laymen witnesses. We may, therefore, safely take the phenomena as physically real and inquire after their probable causes.

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[21] T. Terada, *Nature*, **125** (1930), 528; *Bull. Inst. Phys. Chem. Res.*, **9** (1930), 287.

There are left many points still obscure as to the true nature of the phenonema observed, as is quite natural if we consider that they happened utterly unexpected at the moment of general alarm and passed away rapidly before a few of the witnesses could recover the coolness of mind. Hence, it will not be legitimate to draw any decisive conclusion for the present, but it will be plausible and desirable to enumerate and discuss as many causes as are conceivable, either probable or possible, and thus prepare for the next occasion on which we may hope to obtain more accurate data from those witnesses who are well prepared for observations of the rare phenomena and well aware of the variety of causes as are here enumerated.

(a) Fire-brand. As already mentioned, a conflagration took place in Kôdu before the earthquake which was already extinguished at the monent of the first shock. Fire-brand in Itô broke out after the earthquake and might have been seen from some observers at distant quarters and confounded with the other luminous phenomena. It is, however, difficult to attribute to this cause all kinds of luminosity observed in wide extent, especially those flashes resembling lightning. The ruddy glow seen from Itô above the mountain ridges and the similar phenomena observed at the other localities near the epicentral region coincide in their directions with no fire-brand reported. Besides, the characteristic difference of the nature of the glow compared with that of a fire is emphacized by more than one reliable witnesses. Thence, it may be safely concluded that fire-brand could not have been the main cause of the phenomena observed by the majority of witnesses.

(b) Lightnings. There is no room for the doubt whether some of the luminosity observed were not due to lightning flashes of a remote origin. Consulting the weather maps of that time it is found that the weather in the night was such as is characteristic to any calm and clear winter night, the central part of Honsyû being under the reign of an anticyclonic area. Moreover, according to the reports from local meteorological observatories, no thunderstorm could be traced within the range possible of such a suspicion. It was only in the night of 26th. that thunders are reported from Hatidyôzima and Miyadu, i. e. above 200 km. from the epicentral district, but nowhere else. Thus, the ambiguity due to the simultaneous occurrence of lightning is fortunately got rid of in the present case.

(c) Electric sparking. The question regarding the possibility that the short-circuiting of a powerful transmission line might have been responsible for the flash-light observed in wide extent, cannot be too hastily discarded, though indeed positive testimonies to this effect are yet wanting. There are evidences showing that the electric light got dimmer for a short time or extinguished at the time of earthquake in some locatilies at least. Some state that a transmission line was broken and the others that sparks actually were observed on the line or transformer. Moreover, it seems to be of quite common occurrence that sparkings of transmission lines are observed during an earthquake. It must, therefore, be admitted that at least a part of the luminosity observed was actually due to such causes. At the time of the earthquake no electric tramway was running, so that the usual sparking at the pole of an electric car is quite out of question. The question arises as regards the possible intensity of the light emitted by sparking of a transmission main. In the case of the full display of illumination of a squadron the estimation of the total candle power amounts to 3.10^7 CP. when the electric power consumed is 3000 kw. in round number. In the case of a spark caused by short-circuiting, the efficiency as a light source must be low compared with the above case. Estimating the latter efficiency at 1/10 of that of the former and assuming that a transmission main of 30 000 kw. was made to spark, the result will be same as that of the squadron illumination above quoted and may be sufficient for the sensible illumination of sky to a considerable extent. There is, however, no evidence for assuming that any such powerful main was actually short-circuited and brought about a general extinction of light for a very wide area depending on such a main. Moreover, the above provisory estimation may be probably too high.

On the other hand, there is a class of luminosity observed especially in the epicentral region and described as resembling that of a firebrand and having a considerable duration of time compared with an electric spark, which cannot by all means be explained by an electric sparking. Again, the testimony above given of Mr. Isituti, as reported by Mr. Musya, shows that the light source of another class was seen also at the side of the Lake where no transmission line is running. These phenomena are utterly impossible to be explained by the short-circuiting as above considered. Again, Mr. Kita's observation of a flash at 4 h 10 m seems to be difficult to be attributed to this cause. Prof. T. Itô of the Mineralogical Institute, College of Science, Tôkyô, observed the flash-light at the western suburb of Tôkyô, which was seen to emerge from the distant horizon in the direction of the epicentral region. He observed a sensible after-glow of the sky in in the same direction which he compares to the after-glow of an aurora observed by him in Norway. Such an remarkable after-glow is again utterly difficult to be explained by electric sparking. His observation gives at the same time an evidence to the effect that the after-glow was not quite independent from the flash-light. Hence, it must be admitted that the spark theory cannot cover the entire ground of the phenomena observed.

Lastly, it appears to the author very remarkable that there are so many records of luminous phenomena which are described as resembling to lightnings, but not quite similar to these, either with regards to their duration, or to their colour, and moreover, that the descriptions of these phenomena by the modern witnesses agree in many essential points with those given by the documents, either Japanese or European, dating back to the time when no electric transmission line existed at all.

(c) Land-slides and triboluminecences produced by them. It is known that considerable luminosity is observed on the occasion of land-slides. O. Vogler's and C. L. Griesbach's papers are cited in Sieberg's book in this very respect. The luminosity emitted from chalk-pits, which is mentioned in Milne's "Seismology," may probably belong to the same category. In Prof. B. Kotô's report on Kônô Earthquake, it is stated that some luminous phenomena were seen in connection with the land-slide on the slope of Mt. Ibuki. In the present occasion, some examples have already been given which positively state that some kinds of such phenomena were actually seen accompaying land-slides. It seems, therefore, that the most probable cause of some kinds of the luminosity observed in the present occasion may be attributed to this effect of land-slides. According to the map prepared by the Land Survey Department showing the geographical distribution of land-slides caused by the present earthquake they are quite numerous along the meizoseismal zones, i.e. over seventy, even if we only take the most conspicuous ones into account. The question of after-glow could also be solved by this effect, if we consider that a land-slide may be followed by subsequent series of minor slidings and it may take a sensible time before settling down to the stable state of equilibrium, especially when the earthquake is still continuing to disturb the equilibrium. It is not necessary to inquire after the after-glow effect of triboluminescence itself, which seems to be not yet fully investigated. The question is, however, whether this effect may quantitatively suffice to explain the enormous intensity of luminosity observed. In this respect, the author devised a provisory experiment which was carried out in the Institute of Physical and Chemical Research by the able hands of Dr. M. Hirata and Mr. T. Utigasaki, to whom the best thanks of the author are due. Different kinds of rocks at hand were subjected to grinding by means of a usual tool-grinder in form of a disc which is revolved with an electric motor. The light emitted from the line of contact between the rock specimen and the cylindrical surface of the grinder disc (5 mm. in thickness) was compared with that of 100 lighted "senkô" (incense sticks used by Buddists), by means of a simple Bunsen photometer, as a candle or Hefner lamp was not convenient for the direct comparison. The "100 senkô" light was afterwards compared with a candle by the same photometer. Though the measurement was very rough, it was deemed sufficient for determining the order of magnitude of the luminosity, as such only is here in question. The results of the experiments show firstly that the luminosity is almost independent on the

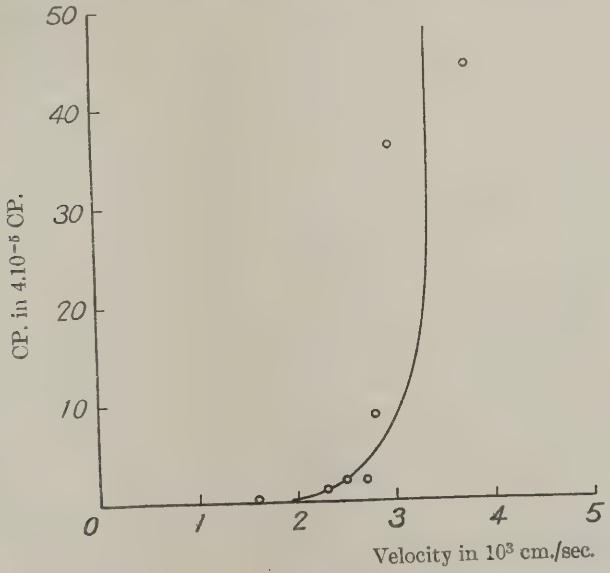

Fig. 1.

pressure between the specimen and the grinder, at least within the range practicable without stopping the motor by the braking action. Secondly, the intensity of light emitted increase with the peripheral velocity of the grinder, first slowly and later rapidly, as shown by Fig. 1, in which the abscissa gives the peripheral velocity in 10^3 cm./sec. and the ordinates in a provisional unit of "100 senkô" which is roughly equivalent to 4.10^{-5} CP. The order of magnitude is not much different for different kinds of rocks tested. Assume now for the sake of estimation that in the area disturbed by a land-slide, every unit area contains l cm. of the luminous line-element similar to that of the line of contact between the rock specimen and the grinder. It will not matter much that in the case of the experiment the two pieces in contact were of different substances. Take the emission per 5 mm. as $p \times 4.10^{-5}$ CP. Then the emission per 1 cm.^{2} of the area will be $pl \times 8.10^{-5}$ CP. Assuming one of the land-slide to be of an area equal to that of a semicircle with the radius of 100 m., the total area of a single slide will be $1{\cdot}57.10^8$ cm.^{2} Thence, the total light for the single slide area will be about $pl \times 12{\cdot}8.10^3$ CP. If one hunderd similar land-slides may be assumed to cooperate at the same time, the total will make $pl \times 1{\cdot}28.10^5$ CP. Hence if we put $p=10$ and $l=10$, the result may become $1{\cdot}28.10^7$ CP. which is of the same order of magnitude as the total CP. of the luminous display of a squadron above cited. It seems, however, that the above is a very exaggerated estimation. Firstly, the entire area affected by land-slide cannot become luminous, since the large relative velocities between consecutive masses of rock can only be sensible at the very slip-plane,(22) so that the effective area must be estimated at most at 1/10 of the above value. Secondly, the assumption $l=10$ means that every cm.^{2} contains 10 cm. of luminous lines, which appears almost incredible, since the finer the grains produced, the more the relative velocity of grains is decreased. Again, $p=10$ is also an over-estimation which according to Fig. corresponds to a velocity of 3×10^3 cm./sec. If the height of fall of a rock mass be h m. which is assumed to fall freely, the velocity aquired is $\sqrt{2hg}$. If $h=50$ m., we obtain a velocity of 31·3 m./sec. which is of the order of magnitude required. In actual case, however, the sliding mass is subjected to a considerable braking action on account of the friction, so that the effective acceleration will be multiplied by a reducing factor equivalent to the difference between the static and kinetic coefficients of friction. Even if $v=20$ m./sec., p is only of the order of unity. Thirdly, it is also an over-estimation to assume that 100 land-slides took place simulaneously to contribute to a single flash of illumination of the sky at a given direction, a fortiori because the solid angle of illumination is always limited by the topographical configurations.

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(22) Different kinds of beam or column of light can be explained if we assume that the light is emitted from the interior of the crevasse formed at the instant of its opening and sliding. A fire-ball might be due to an illuminated spot of cloud.

Thus, putting $l=1$, $p=1$ and the effective area$=1/10$ of the value above assumed, the total candle power is reduced to the order of 10^4. This is still no small figure, but it seems doubtful whether the source of these order of magnitude may explain the observed intensity at a distance of 100 km. The illumination of a source of 10^4 CP. at 100 km. will be equivalent to that of a single candle at 1 km., even if there were no absorbing medium. Hence, the light observed within a house in Tôkyô is difficult to be attributed to this cause. On the other hand, there are some evidences already mentioned showing that at least some of the flash-light observed in Tôkyô are originated from somewhere in epicentral region and not connected with electric sparks.

In the above, the estimation of p was based on the laboratory experiment and given as the function of the relative velocity of sliding. A possibility must be kept in reserve that in the actual case of land-slides in a great scale, another kind of mechanism for producing luminosity may come into play and contribute to increase the value of p to a considerable amount. If some of the old documents, stating emission of light from fissures on ground, may be true, we must take account of such effect which does not depend on the velocity of sliding. Even in that case, it is difficult to assume that the order of magnitude of the luminosity can be quite different. A thorough investigation is, however, desirable on this very respect.

Lastly, it may be remarked that there are some phemomena observed which are not easy to be explained by the luminosity due to land-slides even in qualitative sense, such as the strong luminosity observed towards the southern sky from the vicinity of Simoda, Idu, as no remarkable land-slide is reported from that region and also it is improbable judged from the intensity of shocks in that district. It is, indeed, not yet certain whether a sparking of electric line has not occurred somewhere near Simoda. If we may rely upon the fine sketch made by the witness, the altitude of the concentrated luminosity is seems to have been far too greater than that of any transmission line possible.

(d) A possible cause of luminosity due to the motion of water in the earth's crust.

In the early stage of the author's present investigations, the data from the immediate vicinity of the epicentral region could not yet be obtained; especially, no report was at hand regarding the luminosity observed in connection with land-slides. While seeking then after all conceivable causes of luminosity which may come into play on such an occasion, the author hit upon a possibilty which seems to have been utterly neglected to be taken in account in all previous discussions concerning the phenomena. A preliminary discussion was therefore made on this point and the result was communicated to the Proceedings of Imperial Academy, Vol. VI, 1930, No. 10, p. 401–404.[23] It was shown that the motion of water through subterranean layers containing a network of capillary channels may, under favourable conditions, produce an enormous potential difference in the upper atmosphere and excite a luminous electric discharge in a higher region. The dscussion will be reproduced in the following with little modification.

According to the investigations of Wiedemann, Quincke, Helmholtz and the recent students of "surface chemistry," a potential difference called "Strömungspotential" is established between the two ends of a capillary tube, through which a liquid is made to flow under a pressure gradient. The P.D. is given by

$$E = \frac{\varphi D p \sigma}{4\pi\eta},$$

where φ is the kinetic potential (mostly 0·01–0·05 volts), p the total hydrostatic pressure difference, D, σ and η respectively the dielectric constant, specific resistance, and coefficient of viscosity of the liquid.

For application to the case of earthquake, we will consider here two kinds of "models," for which the juvenile and meteorological waters are the respective working liquids.

(1) The disturbance of a severe earthquake will affect the earth crust to a depth comparable with the linear dimension of the megaseismic

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[23] When later consulting GALLI's paper, loc. cit. the author came across the following passages among the article No. 128, regarding to Andalusian Earthquake of 25 Dec., 1884, quoted as "dai rapporti ufficiali di Formes, Murchas, Nigüelas e Periana": "...ne abbiamo una spiegazione semplicissima quando si ammetta la teoria geodinamica, fondata principalmente sul vapore d'acqua. Questo, infatti, salendo con sufficiente pressione per le fessure, può dare origine ad una manifestazione elettrica, come si ottiene artificialmente nei gabinetti di fisica colla machina Armstrong."

area. We will assume, for example, that the water is displaced vertically upwards through numerous capillary channels existing, or freshly set free in the crust due to the deformation, under a pressure which is of the order of that prevailing in the depth of 100 km. or may be much larger at least for a short time in the case of a catastroph. In that case, P.D. calculated from the above formula will be established between the upper and the lower layers and maintained as long as the flow is continued.

For a rough estimation, we will take $\varphi=0{\cdot}05$ volts, $D=81$, $\sigma=1000$ ohms/cm^3., $\eta=10^{-3}$ c.g.s.[24] For p we take $p=ap_0$, where a is an unknown numerical factor and p_0 the hydrostatic pressure due to 100 km. column of rock with the density of 3, i.e. $p_0=3.10^{10}$ c.g.s.[25] In this case we obtain $E \doteqdot 3{\cdot}3\ a.\ 10^6$ volts. Thus, even if $a=1$, we have a value of 3000 KV.

The value of the potential in the atmosphere depends on the geometrical form of the equipotential surface on the ground. If it be assumed as spherical, with a radius R, the potential at a height H will be $E_H = ER/(R+H)$ and the field $F_H = -ER/(R+H)^2$. The sparking potential of atmosphere is the least at about 60 km. height, where the pressure is of the order of 0·1 mm. Hg. Putting $R = H = 5$ km., the field at the height H is $F_H = -5E.10^{-3}$. If we take the value of E above obtained, then $F_H = -0{\cdot}165$ volts/cm. In the case of the Moore vacuum light, the driving field is about 2 volts/cm. which will require $a = 12$, a value a little too large to be expected. This is, however, not necessary in the present case. The sparking is facilitated by many circumstances such as the heterogeneity[26] in conductivity and the presence of ionisation and space charge. For example, we may expect a considerable increase of the field near the lower boundary of the Heaviside layer. At any rate, the value of P.D. between the layer above the epicentral region and the surrounding atmosphere is far greater than the ordinary cathode fall of any vacuuam discharge, even if we take $a<1$.[27]

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[24] We take this value, since the water may be of a temperature higher than 100°C. For σ we have no available data for subterranean water. Besides, the conductivity of rock in the depth is unknown and if it be large the result of calculation will be sensibly modified. On the other hand, the subterranean water may be in gaseous form in which case no experimental data are available. The fact that an enormous P.D. is produced along the pillar of volcanic dust on the occasion of eruption will show that the kinetic potential between the rock materials and the superheated steam must be of a large value, as in this case also the P.D. is produced by the relative flow of the gas along the heated rock material.

[25] The strength of rock materials against one-sided crushing load is usually of the order of 1000 kg./cm^2.$=10^9$ c.g.s. The hydrostatic pressure in the depth corresponding to such an order of stress difference may be of a higher degree than this strength. This will also support the above assumption for p.

[26] In this repect, the readers are referred to a paper: T. TERADA, U. NAKAYA and K. YUMOTO "Some experiments on spark discharge in heterogeneous media—a hint on the mechanism of lightning discharge," *Sci. Pap. Inst. Phys. Chem. Res.*, 4 (1926), 129–160. It is demonstrated that an abnormally long spark may be drawn under suitable conditions.

The duration of the above phenomena may be short and could not affect the usual recording instrument of the atmospheric potential. Again, the horizontal potential gradient is small, so that the telegraphic lines might not necessarily be sensibly affected.[28]

(2) The meteorological water contained in the water-bearing layer near the ground surface may be forced to a horizontal displacement under the pressure gradient caused by earthquake. In this case the process may be of a more gradual one than in (1). Here we may take $a=1$ and $\eta=0{\cdot}01$ ($t=15°$). Then, $E=3\times10^5$ volts. The head and end of the canal may be compared with a dipole, in roughly estimating the effect at the a great distance. If the length of the dipole be l, we may take $E/l=F_m$ for the field in the middle point of it and compare F_m with the field F_d at a distance ρl. For $l=20$ km. $F_m=1{\cdot}5\times10^{-1}$. K. Shiratori[29] observed a change in earth's potential gradient of about 4.10^{-7} volts/cm. at Sendai, on the occasion of the Kwantô Earthquake of 1923. Thus $F_d/F_m=2{\cdot}7\times10^{-6}$. As the distance of Sendai from the epicentre is about 800 km., $\rho=40$. On the other hand, the field due to a dipole varies as $\rho^{-3}F_m$, disregarding the factor due to the azimuth. The above ρ will therefore give $F_d/F_m=4{\cdot}7\times10^{-6}$, which is of the same order of magnitude as derived above from the observed F_d. Hence, it is possible that the effect observed by Shiratori cannot be merely due to the change in contact potential or resistance of electrodes, but might well have been produced by the real electrical effect of the earthquake.

The case of quadruplets as well as of octuplets may also happen, especially the former in the case of Shida's "pull-push" model.

At the present moment, the above may be taken as a suggestion regarding to a physical possibility, which must at any rate be taken in

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27) In the above model, the case was considered as statical. It may also be possible that a disruptive discharge may take place somewhere in an underground layer and induce an additional field in the atmosphere. Moreover, a large P.D. may already exist in the upper atmosphere before the seismic disturbance, and the latter may then act as a kind of trigger. For the present we may better leave these possibilities as open questions.

28) The magnetic effect may also be small due to the radial nature of the current sheet.

29) K. SHIRATORI, *Jap. Journ. Astr. Geoph.*, 2 (1924), 173.

account, if we attempt to make a thorough investigation of the problem at hand, though the author is far from venturing to explain all the phenomena observed in the present case by this special possible cause(30).

In this connection, it will be of some interest to remark that on the occasion of the Idu Earthquake an unusual fluctuation of current were recorded by the recording system for the submarine cable of Guam Line, though it cannot be ascertained whether it was not due to a merely mechaanical cause. Again, on the occasion of an earthquake in the neighbourhood of Tôkyô on 30th January of this year, a remarkable oscillation was revealed in the recording system(31) of earth-current between Tôkyô and Hôya, while the similar system between Tôkyô and Yokohama showed no trace of such fluctuation of the current. The former circuit is perpendicular to the direction of the epicentre, while the latter is nearly parallel to it. Similar cases may be found frequently in the earlier literatures(32) of earthquake phenomena, though regarded mostly as trivial and neglected by modern students of seismology. It seems, however, not quite superfluous to resume the investigations in this line with improvements of the method which will be possible in these days to be applied for ensuring the reliability of the results far greater than was attainable in the past.

Another fact already mentioned that the cloudiness of sky showed a remarkable abrupt change at the time of earthquake, cannot be overlooked as purely accidental without a further inquiry. It is well known(33) that the formation of cirrus cloud is frequently connected with an auroral display which is a mode of electric discharge in upper air, though the real physical connection between these two phenomena is still obscure.

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30) There remains to be mentioned another electro-capillary effect which is complementary to that of "Strömungspotential," i.e. of "electro-endosmose," by which a hydrostatic pressure gradient may be generated by an electric current. The fact that severe earthquakes seems to take place frequently associated with thunderstorm may be worth attention when viewed under the stand point of the present note.

31) The self-recording apparatuses of the earth-currents have recently been installed by the authorities of the Department of Communication. The records here mentioned were kindly shown to the author by Mr. S. Inada of that Department for which the author feels greatly obliged. The earthquake occurred at 10h 10 m. 41 sec., 30th. Jan., 1931; the epicentre is located at the Kokai-gawa basin; the maximim amplitude in Tôkyô was about 0.4 m.m.

32) Some of them are mentioned in Urbanitzky's book, *loc. cit.*, 917.

33) Arrhennius, "Lehrbuch der komischen Physik," (1903), 907; E. Mathias, "Traité d'electricité atmosphérique et tellurique," (1924), 346; Handbuch der Experimental-Physik, Bd. 25, Teil 1, 472. Also Galli, *loc. cit.*, 439.

It seems therefore interesting to pay attention on this special point in future occasions of severe earthquakes accompanied with, or without, luminous phenomena, and to make a thorough investigation regarding the clouds as well as the general weather conditions before and after the earthquakes.[34]

In concluding, we may repeat that certain classes of the luminous phenomena observed on the occasion of severe earthquakes are physically real and directly connected with the earthquake. The question as to the true cause of the phenomena is not yet settled. The ultimate solution of the problem must be reserved for a future when a more sufficient reliable material of observations would have been accumlated. It is, therefore, desirable that on any future occasion of severe earthquake the seismologists as well as the other scientists capable of reliable observations with open mind would be keenly alive to the appearance of such phenomena and keep detailed records of what were observed.

The author's cordial thanks are due to Mr. Musya who kindly placed his entire collection of data at the author's disposal and not less to many of the scientific members of different Institutes, among which our Earthquake Research Institute, Aeronautical Research Institute and Central Meteorological Observatory must be especially mentioned, for the most reliable data of their personal observations. For the valuable informations regarding the literatures of the subject, he is greatly obliged to Prof. T. Okada, Director of the Central Meteorological Observatory.

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17. 地震に伴ふ發光現象に就て

地震研究所 寺田寅彦

地震の際に空中又は地上に著しい發光を伴ふことがあるといふことは、日本のみならず西洋諸國の地震に關する記事中に多數に發見され、しかも其記事の內容が古今東西を通じて共通な諸點を具備して居るのは興味のあることである。それにも拘らず此現象は從來學者の側からは餘り注意されず、稀に注意されても多くは初から疑の眼をもつて見られ、充分に檢討されなかつた場合が多いやうに見える。昭和五年十一月の伊豆地震に際しても此種の現象が到處で觀測され、此れ

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[34] A similar change of weather happened in the case of Kumamoto Earthquake of 1889 above cited. Other parallel cases are not wanting, e.g. B. Willis, Chile earthquake, loc. cit., though a thorough statical investigation must be carried out in order to make this point clear.

に關する多數の報告を纒めた武者金吉氏の報文は既に本誌前號に掲載された。著者も武者氏蒐集材料と、竝に、少數ではあるが若干の信頼すべき科學者の觀察した材料とを併せ調べた結果、武者氏の結果を確かめることが出來た。

本篇では先づ古來西洋諸國に於ける此現象の文獻を略記し、次には本邦に於ける古來の記錄中から若干の例を採錄し、特に明治以後のものは詳しく列記した。

次に今回の伊豆地震に關する諸資料に就て著者の所見を述べた。(1) 光の見へた場所の分布 (2) 光の現はれた時刻 (3) 光り方の種類 (4) 光の色と (5) 强度等に就て多少の考察を試みた。

又此現象の原因に就て考察した結果は次の通である。(1) 火事と (2) 雷雨に伴ふ電光とは此際問題にならない。(3) 送電線の接觸又切斷によるスパークは、現象の一部を說明するとしても、此れでは說明されない著しい現象がある。さうして其等は (4) 山崩れ地辷りによる tribolumin scence として說明すれば多くの場合に質的には容易に說明されさうである。併し著者が行つた簡單な實驗を基礎として試みた量的の計算 (勿論或假定の下に) の結果では、此れだけで凡ての現象を說明するのは困難であるやうに見える。それで電線のショートと山崩と兩方で凡てを說明すれば一應は尤らしいやうである。併し充分强力な放電に關する確證が得られないのみならず、又電線の存在しなかつた時代に於ける東西兩洋の記錄の共通圈內に多數に現はれる閃光的現象が、今日の場合にショートで說明されるものと殆同一であり、しかもそれが雷雨の疑のない時にでも度々あつたと考へられるところに困難がある。

以上の原因の外に從來全く考慮されなかつたと思はるゝ一つの可能な原因がある。それは毛管電氣現象に關するもので、地殼內に於ける水の運動の爲に地殼中、從て空中に著しき電位差を起こし、場合によつては高層の空中放電を生することが可能であるといふのである。此に關する若干の考察をした結果を述べてある。現在では確に此の爲と考へるべき實證はないが、多少の手掛と見られる二三の現象を附記して將來の參考とした。

武者氏竝に著者の調査によつて、「地震に伴ふ發光現象」の少くも大部分が單なる幻覺ではないこと、又此れが、凡ての場合に火事や、電光や、電線の故障等だけで說明することは出來ないので、兎も角、直接に地震によつて惹起される一つの發光現象が存在することが明になつたと思はれる。

此樣な發光が主なる地震の前から現はれることもありはしないかと疑はせるに足るやうな若干の例もあるので、此點から見ても、此現象は、地震學上必ずしも輕視することの出來ない一つの問題を提供するものであらう。

此研究に關して貴重な材料を供給された武者氏其他多數の舊知又未知の諸君の好意ある援助に對して玆に深謝の意を表する。

18. *Blocks in the Earth's Crust and their Movements. Part I.*[1]

By Naomi MIYABE,

Earthquake Research Institute.

(Read March 17, 1931.—Received June 20, 1931.)

In Kwantô, Tango and other districts, where the leveling or triangulation surveys were carried out more than twice in the same districts, the vertical displacements of bench-marks or triangulation points are generally found which may be considered to have occurred during the time interval of the two successive surveys.

In the preceding paper,[2] the present writer pointed out that the apparent discontinuities in the vertical displacements of bench-marks are due partly to the configuration of the leveling routes. In the present paper, the writer introduced a method to analyse the data of vertical displacements of bench-marks, which might not be affected by the configuration of the leveling routes. Then he investigated block movements of the earth's crust referring to the data of vertical displacements of triangulation points in Bôsô Peninsula.

1. A Method for determining Blocks.

When vertical displacements of bench-marks or triangulation points are given, there may be a number of methods for determining the extent and form of each constituent block and also for investigating its movement. The present writer employed a method described as follows.

Taking pairs of triangulation points, we measure the distance s and the difference of vertical displacements δh between the two triangulation points, together with the azimuth θ of the direction of the line connecting the same pair of triangulation points, with reference to some definite direction, for instance, N. δh is divided by s, the distance between the two triangulation points, and the quotient is put equal to $\tan\phi$, where ϕ denotes the angle of inclination of the line connecting the corresponding pair of the triangulation points.

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[1] An abstract of the present paper was already appeared in *Proc. Imp. Acad.*, 7 (1931), 150.

[2] N. MIYABE, *Bull. E. R. I.*, 9 (1931), 1.

When a number of triangulation points are situated on the same block, θ's and $\tan\phi'$s measured between every pair of these triangulation points are connected by a relation expressed by an equation

$$\tan\phi = \tan\phi_m \cos(\theta - \theta_m), \qquad (1)$$

where ϕ_m and θ_m denote the magnitude and the direction of the tilting of the block, respectively.

Conversely, if a number of triangulation points are such that the measured $\tan\phi'$s and θ's between every pair of them are connected with the relation (1), they are regarded as situated on a single block, ϕ_m and θ_m of which being estimated on the θ-$\tan\phi$ diagramme.

The relation (1), however, holds exactly right when the surface of the block is horizontal before its movement. If the surface of the block is inclined, or, two triangulation points of a pair are situated at portions of different heights, the slope may be expected to affect the value of $\tan\phi$ to some extent. To investigate the effect of the topographical slope, we consider two points A and B situated at different heights (Fig. 1). After a block-movement, B comes to B' relative to A. Let the height-difference

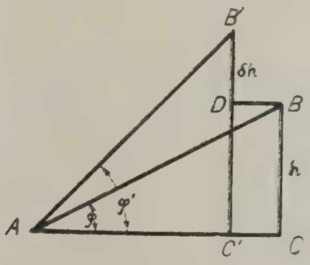

Fig. 1.

measured between A and B and that measured A and B' be h and $h+\delta h$ respectively, and AC be s, then we have

$$\tan\phi = \partial h/s = B'D/AC = (B'C'-DC')/AC = (B'C'-BC)/AC,$$
$$B'C' = AB'\sin\varphi', \qquad BC = AB\sin\varphi,$$
$$AC = AB\cos\varphi, \qquad AB' = AB.$$

Therefore, $\tan\phi = (\sin\varphi' - \sin\varphi)/\cos\varphi.$

Put $\varphi' = \varphi + \varDelta\varphi = \varphi + \phi,$

and we get $\sin\varphi' = \sin(\varphi+\phi) = \sin\varphi\cos\phi + \cos\varphi\sin\phi.$

Now ϕ is small enough for expanding $\cos\phi$ and $\sin\phi$ in terms of ϕ. Hence, we have for the approximation of second order

$$\tan\phi = \frac{\sin\varphi\,(1-\phi^2/2)+\phi\cos\varphi - \sin\varphi}{\cos\varphi}$$
$$= \phi - \phi^2/2\tan\varphi, \qquad (\tan\varphi = BC/AC = h/s)$$

where $-\phi^2/2\tan\varphi$ is a term of correction due to the topographical slope between the two points A and B. The value of the term of correction tends to be infinite, when φ approaches to $\frac{\pi}{2}$. Therefore, the correction due to the slope may not be disregarded when the topographical slope, φ, of the surface of the block is very near to $\frac{\pi}{2}$. But, in most cases, at least in our present case, magnitudes of φ's rarely exceed $\frac{\pi}{4}$. Hence, the correction due to the topographical slope, φ, may be disregarded in our present case.

2. Blocks in Bôsô Peninsula and their Movements.

The above method for determining the form and extent of each constituent block, together with the magnitude and direction of its tilting, was applied to analyse the data of vertical displacements of triangulation points in Bôsô Peninsula. Distances and directions, with reference to N., of lines connecting different pairs of triangulation points are measured on the topographical maps of the scale of 1/50000. Fig. 2 shows the block structure and tilting of each constituent block in Bôsô Peninsula obtained. Lengths and directions of arrows in the figure denote the magnitudes and directions of tiltings of constituent blocks. Dotted lines are probable boundaries of the groups of triangulation points which are regarded as

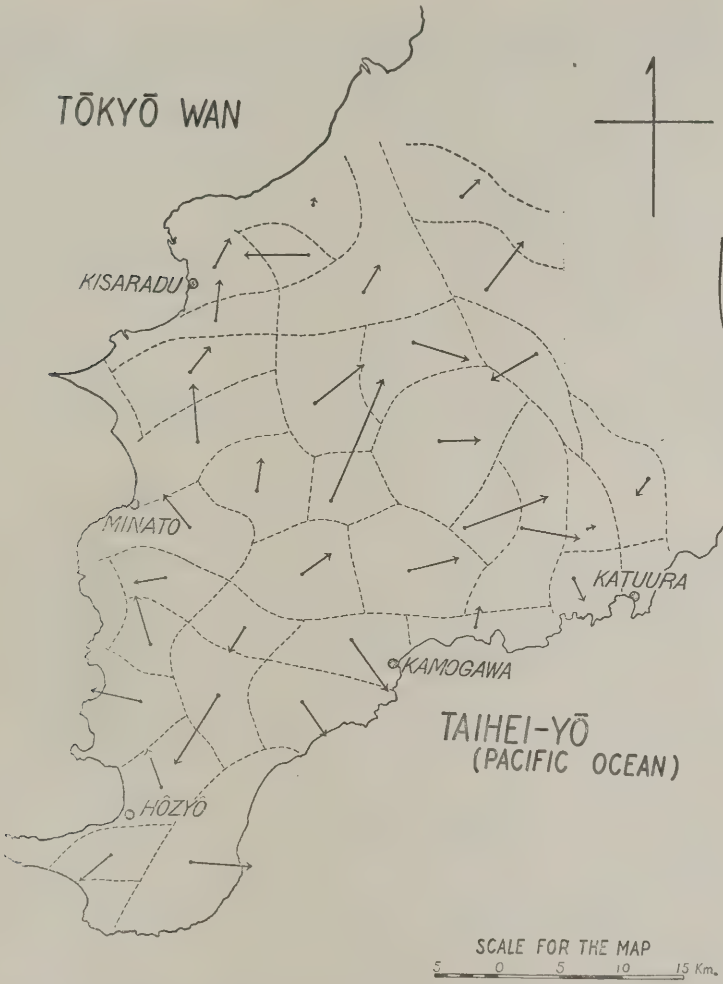

Fig. 2. Blocks and their Tiltings in Bôsô Peninsula.
(The Magnitudes and Directions of the Arrows correspond to those of Tiltings of the Blocks.)

situated on respective blocks. The relation (1) holds in each group of triangulation points or in each constituent block, as shown in Figs. 3, 4 and 5, which correspond to Blocks V, XIX and XXXIII respectively. In these figures, ○'s are the marks for the triangulation points which are regarded as situated on the respective blocks, the tiltings of which are represented by the curves drawn with thick full lines, while, ●'s are the marks for the triangulation points which are not on the same blocks as represented by the curves and the marks ○'s.

Examining the geographical distribution of the directions of tiltings of these blocks, we notice several groups of blocks, in each of which the directions of tiltings of the constituent blocks are approximately the same; for instance, a group of Blocks VIII (107°), XIX (89°), XXI (100°), XXII (73°), XXV (70°) and XXVI (76°) and another group of Blocks V (31°), VI (46°), VII (38°), IX (52°), XVII (55°) and XVIII (23°). The numerical figures in brackets are the values of θ_m's of the blocks. In several other cases, however, the directions of tiltings of adjacent blocks

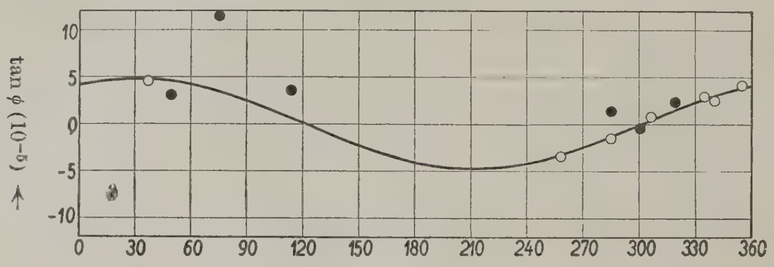

Fig. 3. (Block V).

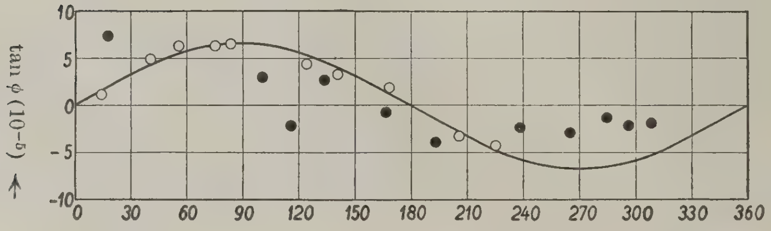

Fig. 4. (Block XIX).

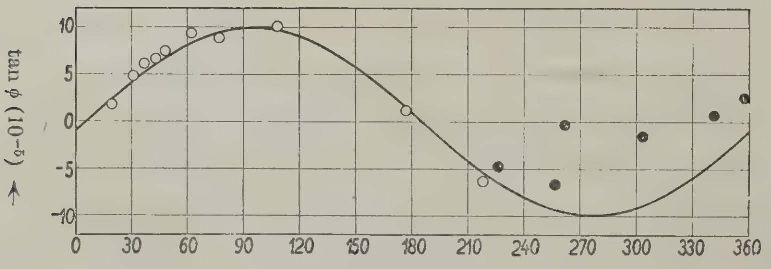

Fig. 5. (Block XXXIII).

are remarkably different; for instance, the directions of tiltings of Blocks VIII (107°), XIX (89°), XXI (100°) and XXII (73°) are much different from those of Blocks XX (240°), XXIII (215°), and the directions of tiltings of Blocks XVII (55°) and XXVI (76°) are much different from those of Blocks XIV (261°), XVI (211°.5) and XXVII (145°).

The boundaries (dots) of the blocks, in Fig. 2, are drawn with no consideration of their geological significances, but they are drawn only to

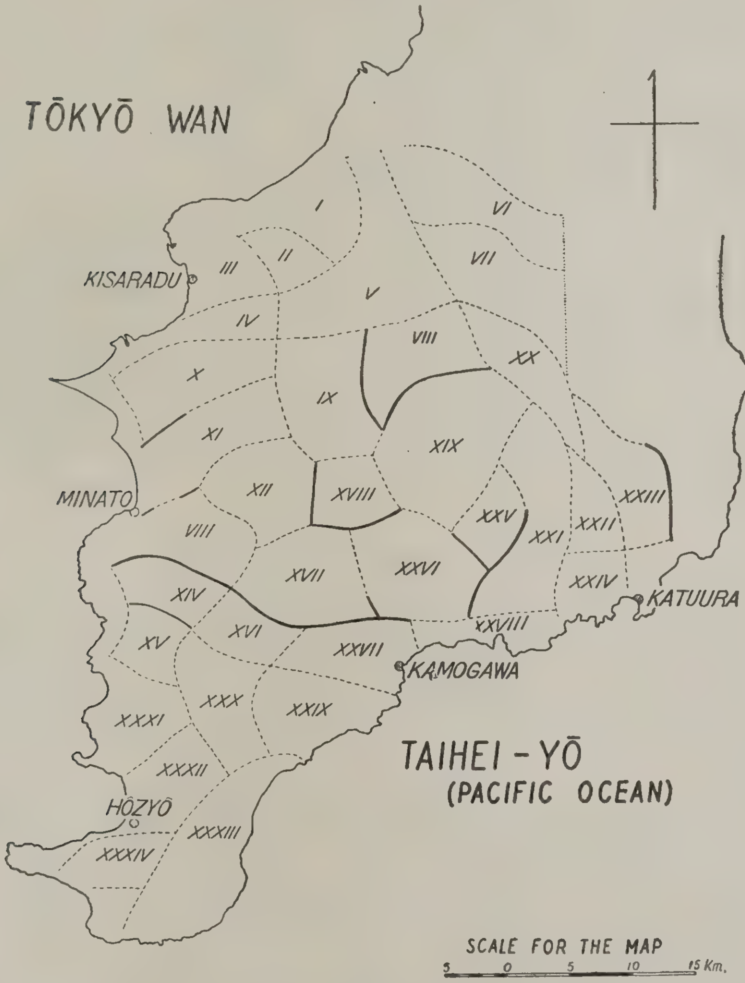

Fig. 6.

Probable Boundaries of the Blocks in Bôsô Peninsula. (The Boundaries coinciding with Tectonic Lines are drawn with Thick Full Lines.)

distinguish the areas within which the triangulation points belonging to respective groups or blocks are distributed. Among them, however, there are found several boundaries which are approximately coincident with the discontinuities significant in geologic structure. In Fig. 6, the boundaries of the blocks which are approximately coincident with geological faults located by Prof. H. YABE and his collaborators,[3] are drawn with full lines, while the boundaries with which the coincident tectonic lines are not yet known are shown by dotted lines.

Among these boundary lines of blocks coinciding with tectonic lines, the boundary lines between the group containing Blocks XIII, XVII and XXVI and that containing Blocks XIV, XVI and XXVII are most remarkable. As for these two groups of the blocks, we have mentioned that the directions of tiltings of the blocks are remarkably different. Corresponding to these boundary lines, there is a well known tectonic line across the peninsula from north of Kamogawa to Nokogiriyama.[4]

It may also be remarked that the result of the present investigation is qualitatively coincident with the result of Messrs. K. MUTÔ and K. ATUMI's investigation "into the result of the New and Old Measurements of the Levelling Net in the Kwantô District." In the present paper, block movements of the earth's crust in Bôsô Peninsula were investigated in more detail than the case of Messrs. K. MUTÔ and K. ATUMI's investigation.

3. Vertical Movements of Blocks.

In the preceding pages, we have exclusively dealt with the tiltings of the blocks. To interprete the full significance of the observed vertical displacements of triangulation points, it is necessary to consider also the translational vertical movements of the blocks as a whole besides the tiltings.

The vertical movement of a block is, in the present investigation, given by the mean value of vertical displacements of triangulation points distributed on the block.

Table I contains vertical movements of the blocks together with

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3) Prof. H. YABE was kind enough to lend me the geological maps of northern part of Bôsô Peninsula compiled by him and his collaborators, at the writer's disposal.

4) R. TAYAMA, *Saitô Hôonkwai, Gakuzyutu Kenkyu Hôkoku,* No. 9 (1930), etc.

5) K. MUTÔ and K. ATUMI, *Bull. E. R. I.,* **7** (1929), 495.

Table I.

Block	φ_m	θ_m (degree)	Vertical Movement
	$\times 10^{-5}$		cm.
I	1·75	10·0	13·7
II	10·44	270·0	25·3
III	5·20	28·0	15·8
IV	6·60	5·0	31·0
V	4·80	31·0	28·3
VI	4·20	46·0	24·8
VII	9·60	38·0	20·7
VIII	9·50	107·0	27·8
IX	10·00	52·0	69·7
X	5·20	38·0	58·3
XI	9·30	355·0	2·7
XII	5·10	7·0	125·6
XIII	6·90	321·5	125·3
XIV	5·10	261·0	126·5
XV	8·20	343·0	132·0
XVI	4·80	211·5	123·3
XVII	5·60	55·0	118·4
XVIII	21·40	23·0	83·3
XIX	6·60	89·0	32·2
XX	8·50	240·0	39·0
XXI	10·20	100·0	54·6
XXII	1·28	73·0	30·8
XXIII	3·10	215·0	29·0
XXIV	4·00	156·0	28·8
XXV	14·40	70·0	32·0
XXVI	8·30	76·0	63·3
XXVII	10·20	145·0	87·2
XXVIII	3·50	11·0	45·7
XXIX	7·00	145·0	102·7
XXX	13·10	212·0	128·3
XXXI	8·20	282·0	128·0
XXXII	6·60	340·0	141·9
XXXIII	9·95	94·0	128·6
XXXIV	6·60	230·0	154·5

the directions and magnitudes of their tiltings. Fig. 7 shows the geographical distribution of vertical movements of the blocks. In Fig. 7,

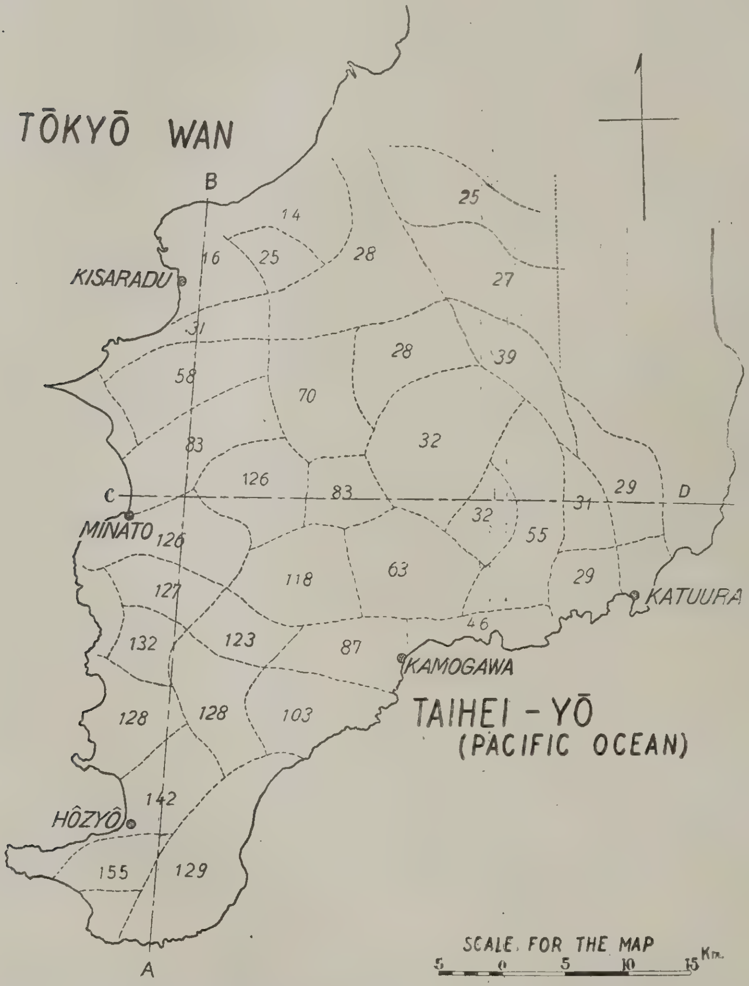

Fig. 7. Translational Vertical Movements of the Blocks in Bôsô Peninsula. (The Numeral Figures are the Amounts of the Vertical Movements in cm.)

we notice three groups of blocks, in each of which the vertical movements of the block are approximately the same.
They are:

1) A group of the blocks situated in the southwestern part of the peninsula, of which the vertical movements are 120–130 cm, including Blocks XXXII (142 cm) and XXXIV (155 cm) with exceptional upheavals;

2) A group of the blocks adjacent to N. and E. of the group 1), of which the vertical movements are 60–80 cm; and

3) A group of the blocks adjacent to N. and E. of the group 2), of which the vertical movements are 20–30 cm, except for Blocks XXI (55 cm) and XXVIII (45 cm) with greater upheavals. Blocks situated in the northern part of this group are less in amounts of vertical movements than those situated in the southern part, by 10 cm or more.

From the result obtained above, we can build a model of block movements in Bôsô Peninsula. Figs. 8 and 9 show the elevations of the model of block movements along the sections *AB* and *CD* of Fig. 7, the scales for the vertical movements and tiltings being much enlarged.

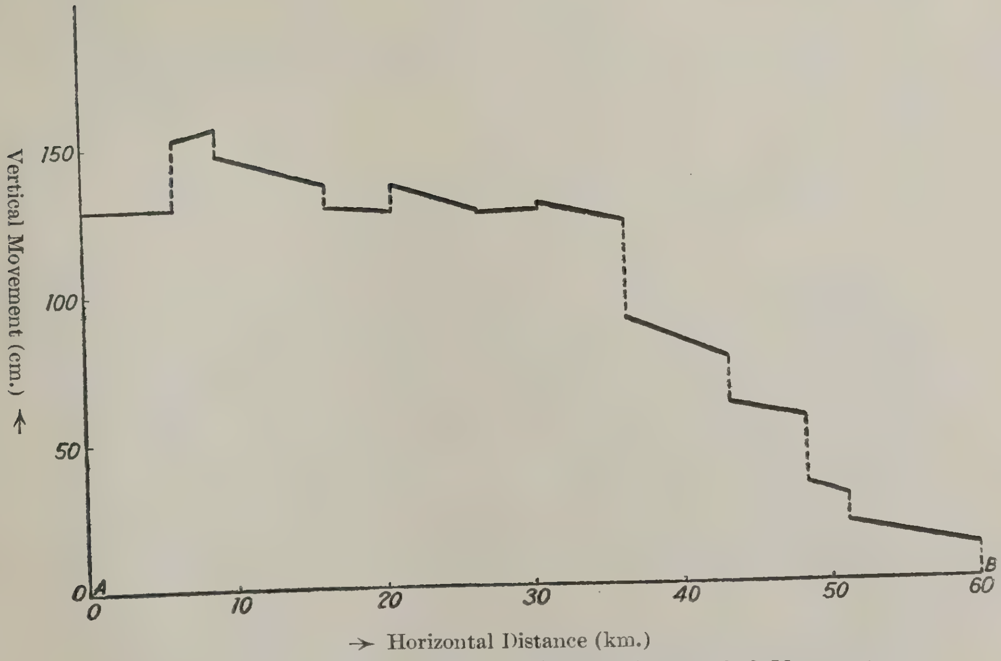

Fig. 8. The Elevation of the Section AB of the Model of the Block-Movements.

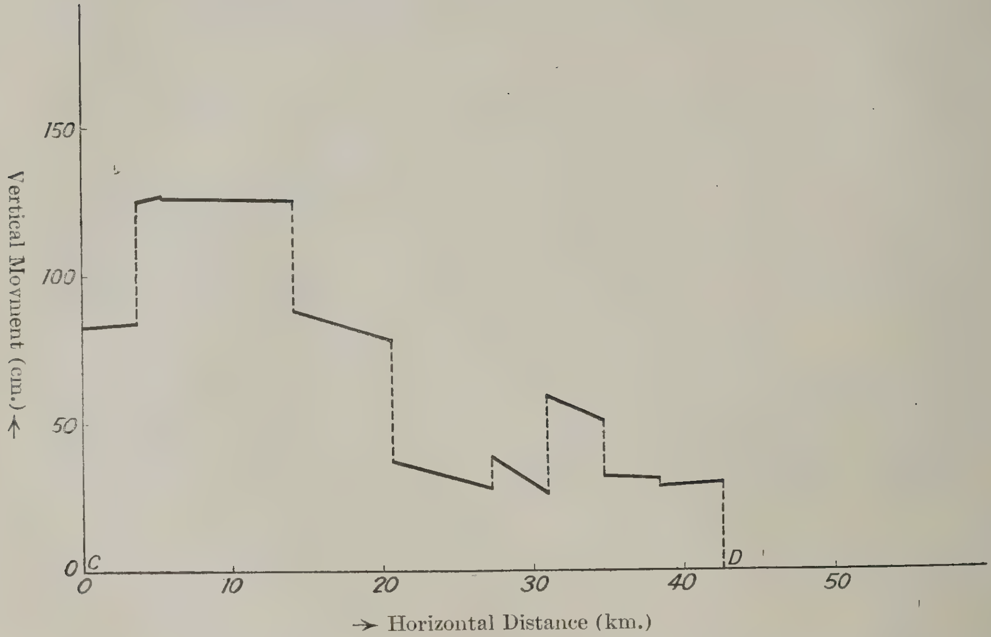

Fig. 9. The Elevation of the Section CD of the Model of the Block-Movements.

4. Horizontal Displacements of Triangulation Points in the District under Consideration.

In the above, we have investigated the block movements referring exclusively to the data of vertical displacements of triangulation points. On the other hand, the horizontal displacements of the triangulation points have been also measured. In the district under consideration, however, the horizontal displacements of triangulation points do not show so evident a block-character, as Dr. C. TSUBOI has found regarding the horizontal displacements of triangulation points in Tango Province.[6] Tables II, III, IV and V contain magnitudes (r) and directions (λ) of

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[6] C. TSUBOI, *Proc. Imp. Acad.*, 6 (1930), 56; *Bull. E. R. I.*, 8 (1930), 153.

Table II. (Block XVII)

Locality of Triangulation Points	r (m)	λ (degree)
Narikawa	1·320	128
Komatimine	1·358	124
Higasikuti	1·270	128
Uenohara	1·310	129
Terakado	1·407	132
Toyooka	1·447	138

Table III. (Block XXVI)

Locality of Triangulation Points	r (m)	λ (degree)
Izumi	1·301	119
Motokiyosumi	1·434	118
Utizumi	1·398	117
Simidu	1·332	119
Kase	1·346	120
Takatenzin	1·258	118
Nisino	1·259	118
Oomi	1·264	121
Suzuri	1·278	124

Table IV. (Block XXVII)

Locality of Triangulation Points	r (m)	λ (degree)
Asamiduka	1·292	127
Issenzyô	1·127	121
Uehara	1·141	117
Hotokeduka	1·259	118
Sengenyama	1·259	118
Mineoka	—	—

Table V. (Block XXIX)

Locality of Triangulation Points	r (m)	λ (degree)
Tenmen	0·781	129
Ogawa	0·706	139
Hasiragi	1·422	148
Kaminoyama	0·564	116
Makado	0·790	129
Karasuba	0·981	134
Dôbone	1·230	143

horizontal displacements of triangulation points distributed respectively on Blocks XVII, XXVI, XXVII and XXIX. As seen in the tables, in Blocks XVII, XXVI and XXVII, the magnitudes and directions of the horizontal displacements of the triangulation points approximately the same, while, in Block XXIX, they are much different from each other. There are many other blocks, in each of which, the magnitudes and directions of the horizontal displacements of the triangulation points are much different from each other, as seen in the case of Block XXIX.

This discordance of magnitudes and directions of the horizontal displacements of the triangulation points within the same block may be due to the facts that the horizontal displacements of the triangulation points are measured relative to certain fixed points,[7] while the block might be deformed in itself. We consider, for simplicity's sake, the case that there is no horizontal deformation in the block. In this case, horizontal displacements of the triangulation points in the block may be the same in both magnitudes and directions, if the horizontal movement of the block was purely translational relative to the fixed points. When, however, the block was rotated about a vertical axis, magnitudes and directions of the horizontal displacements of the triangulation points are expected to be much different from each other. Fig. 10 shows a plan of an ideal case in which the position of a rectangular block *ABCD* (dotted) has changed its position to *A′ B′ C′ D′* (full), after a block movement. The points *a*, *b*, *c*, *d*, *e* and *f* on the block are found to have moved in the directions of respective arrows, the lengths of which denote the magnitudes of the horizontal displacements of the points.

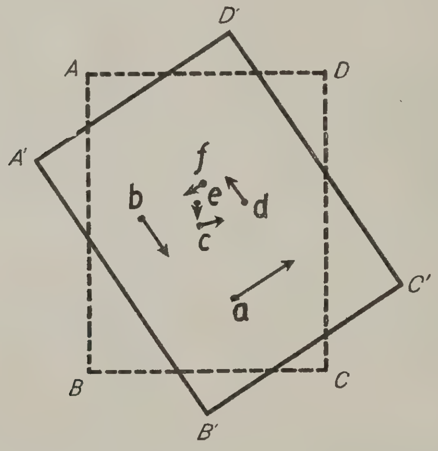

Fig. 10.

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7) On calculating the present data of horizontal displacements of triangulation points in Kwantô District, 6 primary triangulation points were taken as fixed, which are situated in the outermost zone, surrounding the district, where the triangulation points with their horizontal displacements measured are distributed.

As a matter of fact, we notice a similar phenomenon near Rokudizô, one of the fixed primary triangulation points. Fig. 11 shows the horizontal displacements of triangulation points in the neighbourhood of Rokudizô.

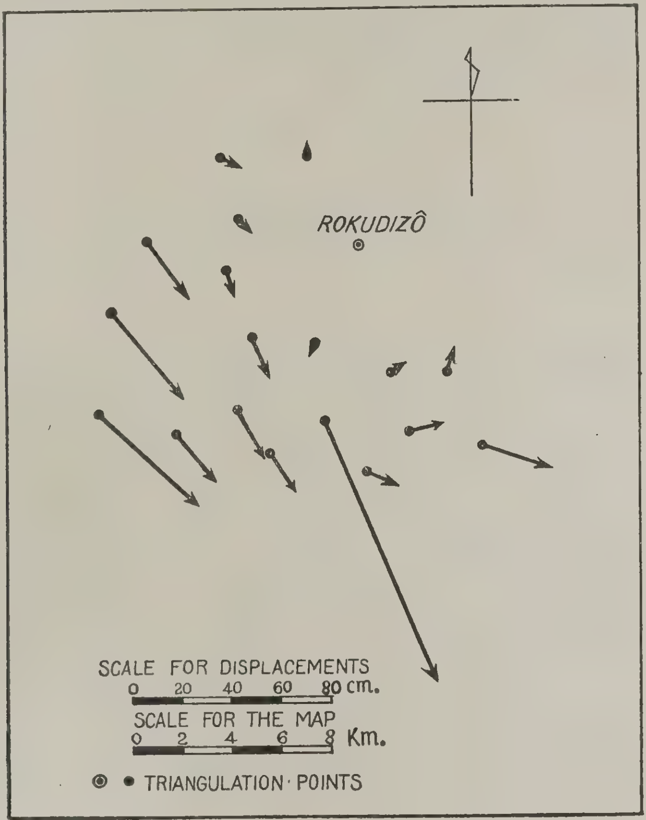

Fig. 11. Horizontal Displacements of Triangulation Points in the Neighbourhood of Rokudizô.

Thus we cannot say that the triangulation points are not on a single block by the mere fact that the magnitudes and directions of their horizontal displacements are much different from each other. Hence, the horizontal displacements of triangulation points are not convenient for determining the forms and extents of constituent blocks in the earth's crust, at least in our present case.

As for the horizontal deformation of each constituent block, the investigation is reserved for a future communication.

In conclusion, the writer wishes to express his sincere thanks to Professor T. TERADA for his kind advices and guidance. The writer's thanks are also due to Professor H. YABE for his kindness in lending the valuable geological maps to the writer, which was compiled by his collaborators.

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18. 地塊とその運動 第一報

地震研究所 宮部直巳

水準點又は三角點の垂直變動量を知つて、地塊及びその傾斜運動を求めやうとする時に、近接する二點の垂直變動量及びそれらの位置から、その二點を結ぶ方向 (θ) 及びその方向に於ける垂直變動量の gradient ($\tan\phi$) を測れば、同一地塊内に在る點については、

$$\tan\phi = \tan\phi_m \cos(\theta - \theta_m) \qquad (1)$$

なる關係が成立つ故、比較的容易に地塊とその傾斜運動とを知ることが出來る。ϕ_m, θ_m は夫々、その地塊の傾斜角度と、傾斜した方向とを示す量である。

筆者は、房總半島内に於ける二三等三角點の垂直變動量を資料とし、(1) の關係を用ひて、同半島内の地塊運動の模樣を調べてみた。

水平移動量については、丹後地方に於ける坪井助教授の見出された樣な地塊的な模樣は見られない。地塊がある垂直軸のまわりに廻轉運動をした樣な場合には、同一地塊内で、水平移動の大いさも方向も異り得る故、水平移動によつて地塊を定めやうとする試は、この場合不適當である。實際の場合についても、上述の樣な模樣が見える。又、前述の方法で定めた地塊内に於ける三角點の水平移動を見ても、そろつてゐるものも二三あるが多くの場合は、同一地塊内で方向も大いさも著しく異つてゐる。

19. *On the Results of Repeated Precise Levellings around Idu Peninsula.*

By **Chûji TSUBOI**,

Earthquake Research Institute.

(Read March 17, 1931.—Received June 20, 1931.)

Introduction.

The peninsula of Idu, on the Pacific coast of Central Japan, was recently attacked by three successive seismic disturbances. The first one of them was due to the Kwantô earthquake of Sept. 1, 1923, the second due to the Ito earthquake swarms of 1930, and the third due to the North Idu destructive earthquake of Nov. 26, 1930. With the hope of detecting, if any, of the changes of land levels in the peninsula connected with these seismic disturbances, precise levellings have been repeated three times around the peninsula as well as in its neighbouring regions by the Land Survey Department of the Imperial Army. The results of these measurements were recently placed at our disposal which are the object of the present paper to discuss. The levelling route covered by these surveys is shown in Fig. 1 together with the ordinal numbers of the bench-marks in the route. The first levelling survey was made about 30 years ago, the second one immediately after the occurrence of the Kwantô earthquake of 1923 but before that of the Idu earthquake of 1930, and the third one after the occurrence of the last mentioned earthquake. These three surveys will be referred to in this paper as I, II, and III according as their chronological orders. The changes of heights of the bench-marks on the levelling route as found by means of these levellings are tabulated in the following tables. The changes of heights of the bench marks are graphically shown in Figs. 2, 7, and 10. Generally speaking, the peninsula has been dipping southwards, especially in the interval (III–II). Remarkable changes of heights of bench-marks are found at B.M. 9400 in Fig. 2, B.M. 55.1 in Fig. 7, and B.M. 9337 in Fig. 10. They will be discussed in detail in the following chapters.

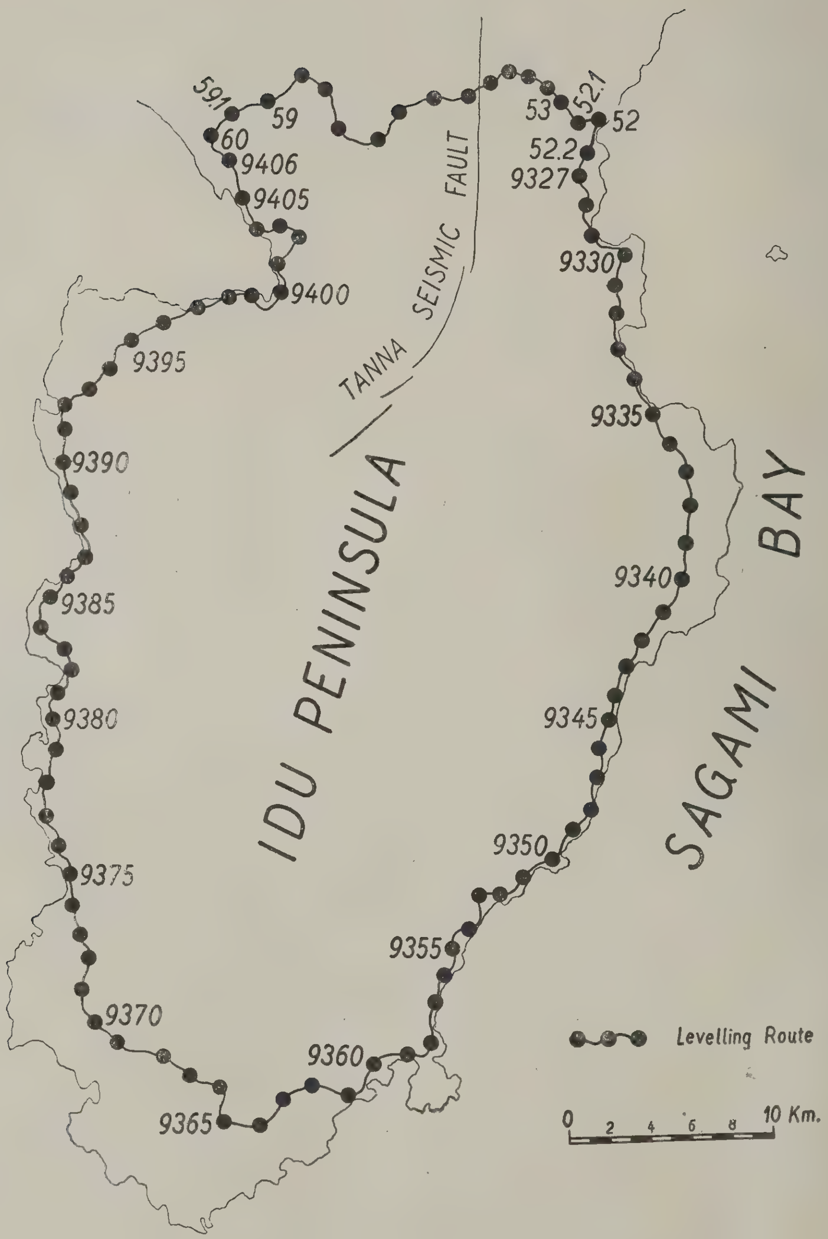


Fig. 1.
Levelling Route Around and Across Idu Peninsula.

Table I.

Change of Heights along the Western Coast of the Peninsula.

B. M.		I	II–I	II	III–II	III
			mm		mm	
60	Numadu	1903	− 84·3	1924	+ 17·0	Dec. 21, 25, 1930
9406		„	− 91·9	„	+ 14·2	„ 20, 21
9405	Sisigahama	„	− 89·7	„	+ 20·2	„ 20
9404		„	−114·2	1929	+ 27·8	„ 18
9403		„	−109·0	„	+ 46·1	„ 17, 18
9402		„	−110·1	„	+ 64·3	„ 17, 19
9401		„	−106·9	„	+ 64·9	„ 11, 12
9400	Mito	„	− 94·4	„	+ 74·6	„ 12, 16
9399		„	−104·8	„	+ 61·6	„ 14
9398		„	−113·6	„	+ 51·2	„ 9, 10
9397	Kou	„	−126·0	„	+ 34·2	„ 10, 12
9396		„	−125·7	„	+ 30·8	„ 12, 14
9395		„	−101·7	„	+ 21·4	„ 14, 18
9394		„	− 98·6	„	+ 19·2	„ 20, 26
9393		„	−113·6	„	+ 12·5	„ 17, 20
9392	Hata	„	−132·5	„	− 3·0	„ 21, 23
9391		„	−114·3	„	+ 4·9	Dec. 27, 1930, Jan. 10, 1931
9390		„	−125·1	„	− 1·8	Jan. 4, 1931,
9389		„	−102·2	„	− 3·4	„ 2, 4
9388	Tohi	„	−113·7	„	− 12·3	„ 5
9387		„	−126·1	„	− 23·0	„ 7
9386		„	−102·4	„	− 11·9	„ 8, 12
9385	Kosimoda	„	−101·4	„	− 8·8	„ 12, 13
9384		„	− 99·2	„	− 8·3	„ 14, 15
9383		„	− 96·0	„	− 4·5	„ 16, 22
9382	Ukusu	„	− 84·5	„	− 15·7	„ 18, 19
9381		„	− 91·6	„	− 14·2	„ 18, 22
9380		„	− 88·1	„	− 10·0	„ 14, 15
9379		„	− 79·5	„	− 10·4	„ 11, 13
9378	Tago	„	− 76·0	„	− 13·3	„ 15, 16
9377		„	− 86·6	„	− 14·8	„ 17
9376		„	− 80·8	„	− 17·3	„ 5
9375		„	−110·3	„	− 19·9	„ 2
9374	Matuzaki	„	− 92·5	„	− 20·5	Dec. 28, 31, 1930
9373	Iwasina	„	− 90·8	„	− 22·1	„ 28, 31
9372		„	− 83·5	„	− 23·4	Jan. 3, 7, 1931
9371		„	− 72·8	„	− 29·8	Dec. 24, 26, 1930
9370	Zyaisi		− 78·6		− 28·7	

Table II.

Change of Heights across the Tanna Seismic Fault.

B. M.		I	II–I	II	III–II	III
			mm		mm	
52	Atami	1896	+ 43·5	1924	+ 92·1	Dec. 10, 12, 1930
52.1		"	− 40·0	"	+ 89·1	" 11, 13
53		"	− 6·1	"	+101·4	" 14, 13
53.1		"	− 39·9	"	+ 94·5	" 16, 18
54		"	− 48·3	"	−	" 23, 25
54.1		"	− 55·6	"	+ 47·7	" 22, 26
55	Karuizawa	"	−	"	−132·8	" 26, 37
55.1		"	− 80·8	"	−197·8	" 27, 31
56		"	− 95·5	"	− 52·5	Jan. 3, 1931
56.1	Hirai	"	− 77·9	"	− 7·7	" 2, 5
57	Daiba	"	− 74·0	"	+ 36·1	" 2, 5
57.1		"	−125·6	"	− 0·6	" 2, 5
58		"	−110·1	"	− 10·6	" 7,
58.1	Misima	"	− 96·4	"	− 6·1	" 9,
59		"	− 88·6	"	+ 6·5	" 10, 11
59.1		"	− 80·7	"	+ 19·5	" 12,
60	Numadu		− 84·3		+ 17·0	

Table III.

Change of Heights along the Eastern Coast of the Peninsula.

B. M.		I	II–I	II	III–II	III
			mm		mm	
52	Atami	1903	+ 43·5	1923	+ 92.1	Dec. 9, 10, 1930
52.2		"	− 25·5	"	+ 72·7	" 10, 16
9327		"	+ 18·8	"	+ 58·0	" 12, 15
9328	Kamitaga	"	− 9·6	"	+ 69·0	" 19, 20
9329		"	− 33·2	"	+ 50·7	" 19, 20
9330		"	+ 88·0	"	+ 77·6	" 21, 25
9331		"	+ 57·5	"	+ 93·8	" 22, 24
9332	Aziro	"	+ 52·0	"	+134·4	" 26, 27

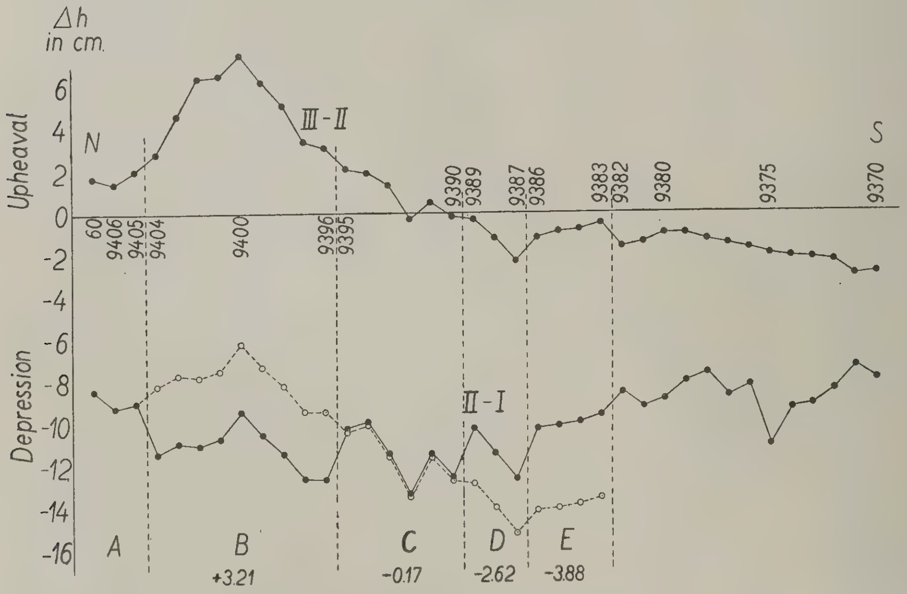
(*to be continued.*)

Table III. (*continued.*)

B. M.		I	II–I	II	III–II	III
			mm		mm	
9333		1903	+ 31·5	1923	+168·0	Dec. 26, 27
9334		,,	—	,,	+210·5	,, 26, 27
9335	Itô	,,	− 6·8	,,	+259·7	Dec. 28, 1930. Jan. 2, 1931.
9336		,,	− 9·6	,,	+288·3	Dec. 28, 31
9337	Yosida	,,	− 29·1	1924	+292·5	,, 30, 31
9338		,,	− 44·0	,,	+250·8	Jan. 3, 15 1931
9339	Sakihara	,,	− 69·4	,,	+193·0	,, 3, 15
9340		,,	− 63·1	,,	+140·7	,, 4, 16
9341	Yawatano	,,	− 57·8	,,	+ 97·2	,, 4, 13
9342		,,	− 51·8	,,	+ 68·0	,, 5, 13
9343		,,	− 40·7	,,	+ 54·3	,, 10, 11
9344	Ookawa	,,	− 34·3	,,	+ 33·2	,, 17, 18
9345		,,	− 33·4	,,	+ 30·2	,, 15, 18
9346		,,	− 33·4	,,	+ 24·7	,, 11, 18
9347	Katase	,,	− 33·5	,,	+ 16·9	,, 12, 13
9348		,,	− 36·1	,,	+ 17·2	,, 9, 12
9349	Inatori	,,	− 31·5	,,	+ 16·8	,, 5, 10
9350		,,	− 24·4	,,	+ 11·1	Dec. 30, 31, 1930
9351		,,	− 26·5	,,	+ 11·0	{Dec. 28, 1930, Jan. 2, 1931
9352		,,	− 25·6	,,	+ 3·9	Dec. 27, 28, 1930
9353	Kôduhama	,,	− 36·4	,,	+ 0·6	Dec. 26, 27, 1930
9354		,,	− 42·3	,,	+ 4·5	,, 23, 26
9355		,,	− 35·8	,,	+ 2·1	,, 19, 22
9356		,,	− 32·4	,,	+ 0·5	,, 16, 17
9357	Sirahama	,,	− 37·1	,,	− 2·8	,, 14, 15
9358		,,	− 47·0	,,	− 0·3	,, 11, 13
9359	Simoda	,,	—	,,	− 5·7	,, 10
9360		,,	− 47·4	1929	− 5·1	,, 10, 12
9361		,,	− 46·9	,,	− 10·0	,, 12
9362		,,	− 48·6	,,	− 12·3	,, 13
9363	Simogamo	,,	− 61·1	,,	− 17·5	,, 15
9364		,,	− 61·6	,,	− 17·9	,, 16, 18
9365		,,	− 67·9	,,	− 21·9	,, 17
9366		,,	− 61·7	,,	− 21·9	,, 18
9367	Simoono	,,	− 63·3	,,	− 20·6	,, 20
9368		,,	− 64·4	,,	− 20·8	,, 20, 21
9369		,,	−− 69·2	,,	− 30·0	,, 22, 23
9370	Zyaisi		− 78·6		− 28·7	

The Results of the Levelling along the Western Coast of Idu Peninsula.[1]

The changes of heights of the bench-marks along the western coast of the peninsula are shown in Fig. 2. The curve (II–I) shows the changes in the interval between II and I, while the curve (III–II) those in the interval between III and II. The former changes are to be regarded as mainly due to the effect of the earthquake of 1923 and the latter ones to that of the earthquake of 1930. If we compare these two curves, we find that a number of segments or portions such as A, B, C, D, and E that are quite similar in their forms for both curves are commonly involved in them. For the segment B, the form of the curve is very much characteristic. The levelling route from B.M. 9404 to B.M. 9396 corresponding to the segment B is not straight but goes winding as may be seen in Fig. 1, thus the peculiar form of the curves of Fig. 2 corresponding to the segment B may be produced purely as a geometrical effect even if the land



Change of Level along the Western Coast of Idu Peninsula

Fig. 2.

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1) C. TSUBOI, *Proc. Imp. Acad.*, 7 (1931), 158.

between B.M. 9404 and B.M. 9396 is subjected to a single tilting as a whole. For the purpose of determining whether this is actually the case or not, the method due to my colleage Mr. N. Miyabe[2] is exclusively effective. If the land between B.M. 9404 and B.M. 9396 is assumed to have undergone a single tilting, then the difference of changes in heights of any two points lying on this land whose distance is of a unit length, must be a sinusoidal function of the directional azimuth of the line connecting these two points with respect to a definite reference direction, say E. The difference per unit distance of changes in heights in different azimuths may be obtained by dividing the difference of changes of heights of any two of the bench-marks between B.M. 9404 and B.M. 9396 by the distance between these marks. In Table IV will be given these quotients obtained for (II–I) and (III–II) together with the corresponding azimuths, distances, and differences in height changes.

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2) N. Miyabe, *Proc. Imp. Acad.*, 7 (1931), 150.

Table IV.

Section B. Bench-Marks 9396; 9397; 9398; 9399; 9400; 9401; 9402; 9403; 9404.

Azimuth

From \ To	9396	9397	9398	9399	9400	9401	9402	9403	9404
9396	—	+25°	+23°	+15°	+12°	+27°	+32°	+ 41°	+ 46°
9397	−155°	—	+22°	+ 9°	+ 7°	+27°	+33°	+ 45°	+ 53°
9398	−157°	−158°	—	− 4°	− 1°	+30°	+37°	+ 53°	+ 64°
9399	−165°	−171°	+176°	—	+ 2°	+55°	+53°	+ 71°	+ 87°
9400	−168°	−173°	−179°	−178°	—	+94°	+72°	+ 90°	+107°
9401	−153°	−153°	−150°	−125°	− 86°	—	+50°	+ 88°	+117°
9402	−148°	−147°	−143°	−127°	−108°	−130°	—	+139°	+162°
9403	−139°	−135°	−127°	−109°	− 90°	− 92°	−41°	—	−169°
9404	−134°	−127°	− 16°	− 93°	− 73°	− 63°	−18°	+ 11°	—

Distance in km.

From \ To	9396	9397	9398	9399	9400	9401	9402	9403	9404
9396	—	1·65	3·10	4·45	5·65	6·10	7·70	7·25	6·40
9397	1·65	—	1·50	2·85	4·05	4·40	5·90	5·70	4·90
9398	3·10	1·50	—	1·45	2·70	3·00	4·45	4·35	3·70
9399	4·45	2·85	1·45	—	1·25	1·95	3·50	3·75	3·40
9400	5·65	4·05	2·70	1·25	—	1·55	2·85	3·50	3·50
9401	6·10	4·40	3·00	1·95	1·55	—	1·50	1·95	2·00
9402	7·70	5·90	4·45	3·50	2·85	1·50	—	1·20	2·00
9403	7·25	5·70	4·35	3·75	3·50	1·95	1·20	—	2·00
9404	6·40	4·90	3·70	3·40	3·50	2·00	2·00	2·00	—

Difference of Change of Height for (II-I) in mm.

From \ To	9396	9397	9398	9399	9400	9401	9402	9403	9404
9396	—	+ 0·3	+12·1	+20·9	+31·3	+18·8	+15·6	+16·7	+11·5
9397	− 0·3	—	+12·4	+21·2	+31·6	+19·1	+15·9	+17·0	+11·8
9398	−12·1	−12·4	—	+ 8·8	+19·2	+ 6·7	+ 3·5	+ 4·6	− 0·6
9399	−20·9	−21·2	− 8·8	—	+10·4	− 2·1	− 7·3	− 4·2	− 9·4
9400	−31·3	−31·6	−19·2	−10·4	—	−12·5	−15·7	−14·6	−19·8
9401	−18·8	−19·1	− 6·7	+ 2·1	+12·5	—	− 3·2	− 2·1	− 7·3
9402	−15·6	−15·9	− 3·5	+ 7·3	+15·7	+ 3·2	—	+ 1·1	− 4·1
9403	−16·7	−17·0	− 4·6	+ 4·2	+14·6	+ 2·1	− 1·1	—	− 5·2
9404	−11·5	−11·8	+ 0·6	+ 9·4	+19·8	+ 7·3	+ 4·1	+ 5·2	—

Table IV.

Inclination for (II-I) in 10^{-6}

To From	9396	9397	9398	9399	9400	9401	9402	9403	9404
9396	—	+0·2	+3·9	+4·7	+5·5	+3·1	+2·0	+2·3	+1·8
9397	−0·2	—	+8·3	+7·4	+7·8	+4·3	+2·7	+3·0	+2·4
9398	−3·9	−8·3	—	+6·1	+7·1	+2·2	+0·8	+1·1	−0·2
9399	−4·7	−7·4	−6·1	—	+8·3	−1·1	−2·1	−1·1	−2·8
9400	−5·5	−7·8	−7·1	−8·3	—	−8·1	−5·5	−4·2	−5·7
9401	−3·1	−4·3	−2·2	+1·1	+8·1	—	−2·1	−1·1	−3·7
9402	−2·0	−2·7	−0·8	+2·1	+5·5	+2·1	—	+0·9	−2·1
9403	−2·3	−3·0	−1·1	+1·1	+4·2	+1·1	−0·9	—	−2·6
9404	−1·8	−2·4	+0·2	+2·8	+5·7	+3·7	+2·1	+2·6	—

Difference of Change of Height for (III-II) in mm.

To From	9396	9397	9398	9399	9400	9401	9402	9403	9404
9396	—	+ 3·4	+20·4	+30·8	+43·8	+34·1	+33·5	+15·3	− 3·0
9397	− 3·4	—	+17·0	+27·4	+40·4	+30·7	+30·1	+11·9	− 6·4
9398	−20·4	−17·0	—	+10·4	+23·4	+13·7	+13·1	− 5·1	−23·4
9399	−30·8	−27·4	−10·4	—	+13·0	+ 3·3	+ 2·7	−15·5	−33·8
9400	−43·8	−40·4	−23·4	−13·0	—	− 9·7	−10·3	−18·5	−46·8
9401	−34·1	−30·7	−13·7	− 3·3	+ 9·7	—	− 0·6	−18·8	−17·1
9402	−33·5	−30·1	−13·1	− 2·7	+10·3	+ 0·6	—	−18·2	−36·5
9403	−15·3	−11·9	+ 5·1	+15·5	+18·5	+18·8	+18·2	—	−18·3
9404	+ 3·0	+ 6·4	+23·4	+33·8	+46·8	+17·1	+36·5	+18·3	—

Inclination for (III-II) in 10^{-6}

To From	9396	9397	9398	9399	9400	9401	9402	9403	9404
9396	—	+ 2·0	+ 6·6	+ 7·0	+ 7·8	+ 5·6	+ 4·4	+ 2·2	− 0·4
9397	− 2·0	—	+11·4	+ 9·6	+10·0	+ 7·0	+ 5·0	+ 2·0	− 1·4
9398	− 6·6	−11·4	—	+ 7·2	+ 8·6	+ 4·6	+ 3·0	− 1·2	− 6·4
9399	− 7·0	− 9·6	− 7·2	—	+10·4	+ 1·6	+ 0·8	− 4·2	−10·0
9400	− 7·8	−10·0	− 8·6	−10·4	—	− 6·0	− 3·6	− 5·2	−13·4
9401	− 5·6	− 7·0	− 4·6	− 1·6	+ 6·0	—	− 0·4	− 9·6	− 8·6
9402	− 4·4	− 5·0	− 3·0	− 0·8	+ 3·6	+ 0·4	—	−15·2	−18·2
9403	− 2·2	− 2·0	+ 1·2	+ 4·2	+ 5·2	+ 9·6	+15·2	—	− 9·2
9404	+ 0·4	+ 1·4	+ 6·4	+10·0	+13·4	+ 8·6	+18·2	+ 9·2	—

The results given in Table IV are shown graphically in Figs. 3 and 4. As a matter of fact, the points in the figures are distributed approximately on a sine-curve whose equations are

$$y = 1.''8 \sin (50^\circ - \alpha) \qquad \text{for (II—I)}$$
$$y = 3.''5 \sin (50^\circ - \alpha) \qquad \text{for (III—II)}$$

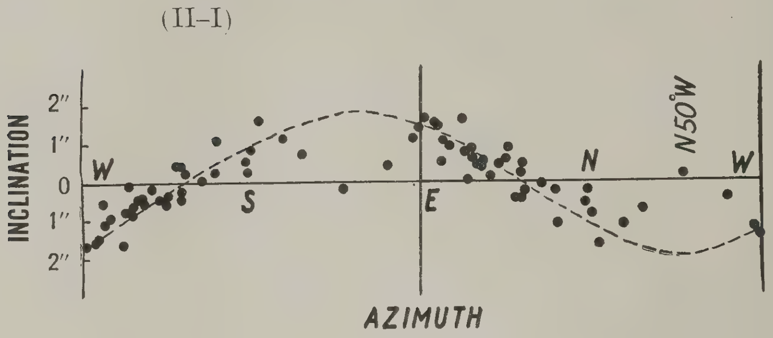

Fig. 3.

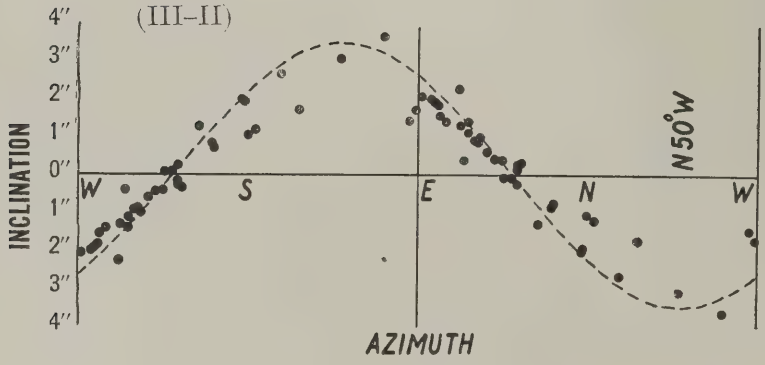

Fig. 4.

This is evidently a proof that the land between B.M. 9404 and B.M. 9396 underwent for both intervals (II—I) and (III—II), a tilting as a whole making a movement what we call a block movement. The tilting was evidently down towards N 50°W for both cases and it was about 2'' and 3.5'' in its amount for the former and latter intervals respectively. It is interesting that the directions of the tiltings were just the same for both of the intervals. For other sections of the levelling routes, such as A, C, D, and E, the tiltings were similarly calculated. The results of these calculations are summarised in Tables V, VI, VII, VIII and some of them are graphically shown in Figs. 5 and 6.

Table V.

Section A. Bench Marks, 60; 9405; 9406.

Azimuth

From / To	9405	9406	60
9405	—	111°	116°
9406	−69°	—	122°
60	−64°	−58°	—

Inclination for (II-I) in 10^{-6}

From / To	9405	9406	60
9405	—	− 1·2	+ 1·5
9406	+ 1·2	—	+ 4·8
60	− 1·5	− 4·8	—

Direction of Tilting: N 70° E

Magnitude of Tilting: 4″

Inclination for (III-II) in 10^{-6}

From / To	9405	9406	60
9405	—	− 3·2	− 0·9
9406	+ 3·2	—	+ 1·8
60	+ 0·9	− 1·8	—

Direction of Tilting: N 60° E

Magnitude of Tilting: 4″

Table VI.

Section C. Bench Marks, 9390; 9391; 9392; 9393; 9394; 9395.

Azimuth

From / To	9390	9391	9392	9393	9394	9395
9390	—	84°	89°	66°	60°	59°
9391	− 96°	—	95°	54°	50°	51°
9392	− 91°	− 85°	—	26°	33°	41°
9393	−114°	−126°	−154°	—	43°	50°
9394	−120°	−130°	−147°	−137°	—	55°
9395	−121°	−129°	−139°	−130°	−125°	—

Table VI.

Inclination for (II-I) in 10^{-6}

From \ To	9390	9391	9392	9393	9394	9395
9390	–	+ 6·8	– 2·6	+ 2·9	+ 5·1	+ 3·4
9391	– 6·8	–	– 14·6	+ 0·3	+ 4·2	+ 2·3
9392	+ 2·6	+14·6	–	+ 9·5	+10·9	+ 6·4
9393	– 2·9	– 0·3	– 9·5	–	+10·7	+ 3·8
9394	– 5·1	– 4·2	–10·9	–10·7	–	– 1·7
9395	– 3·4	– 2·3	– 6·4	– 3·8	+ 1·7	–

Direction of Tilting N 60° W, Magnitude of Tilting 4·5″

Inclination for (III-II) in 10^{-6}

From \ To	9390	9391	9392	9393	9394	9395
9390	–	+ 4·2	– 0·4	+ 3·6	+ 4·0	+ 3·3
9391	– 4·2	–	– 6·3	+ 3·1	+ 3·6	+ 2·9
9392	+ 0·4	+ 6·3	–	+ 7·9	+ 7·2	+ 5·1
9393	– 3·6	– 3·1	– 7·9	–	+ 4·8	+ 2·8
9394	– 4·0	– 3·6	– 7·2	– 4·8	–	+ 1·2
9395	– 3·3	– 2·9	– 5·1	– 2·8	– 1·2	–

Direction of Tilting N 70° W, Magnitude of Tilting 2.″5

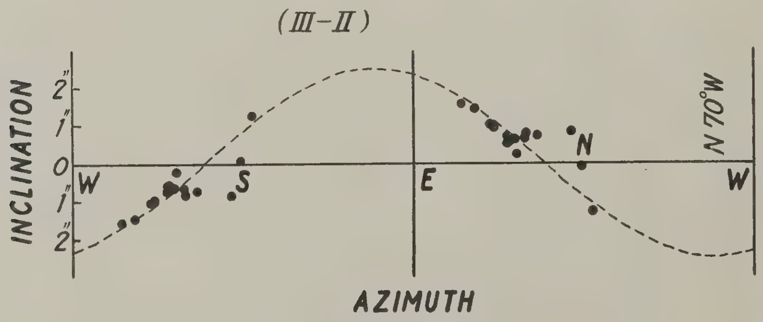

Fig. 5.

Table VII.

Section D. Bench Marks, 9389 ; 9388 ; 9387.

Azimuth

To From	9389	9388	9387
9389	—	−74°	−77°
9388	106°	—	−81°
9387	103°	99°	—

Inclination for (II-I) in 10^{-6}

To From	9389	9388	9387
9389	—	−7·2	−7·6
9388	+7·2	—	−7·8
9387	+7·6	+7·8	—

Direction of Tilting: S 20° W

Magnitude of Tilting: 2″

Inclination for (III-II) in 10^{-6}

To From	9389	9388	9387
9389	—	−5·6	−6·2
9388	+5·6	—	−6·7
9387	+6·2	+6·7	—

Direction of Tilting: S 40° W

Magnitude of Tilting: 2″

Table VIII.

Section E. Bench Marks, 9386 ; 9385 ; 9384 ; 9383.

Azimuth

To From	9386	9385	9384	9383
9386	—	−132°	−120°	− 96°
9385	48°	—	−109°	− 77°
9384	60°	71°	—	− 46°
9383	84°	103°	134°	—

Table VIII.

Inclintion for (II-I) in 10^{-6}

From \ To	9386	9385	9384	9383
9386	–	+ 0·7	+ 1·1	+ 1·8
9385	– 0·7	–	+ 1·4	+ 2·1
9384	– 1·1	– 1·4	–	+ 2·1
9383	– 1·8	– 2·1	– 2·1	–

Direction of Tilting: N 30° W
Magnitude of Tilting : 0·″4

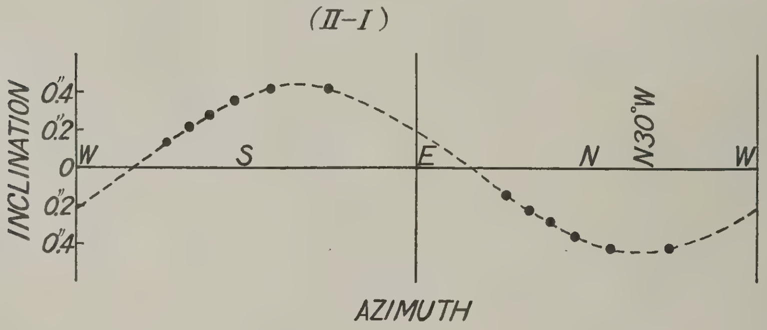

Fig. 6.

Inclination for (III-II) in 10^{-6}

From \ To	9386	9385	9384	9383
9386	–	+ 2·1	+ 1·2	+ 2·0
9385	– 2·1	–	+ 0·3	+ 1·7
9384	– 1·2	– 0·3	–	+ 2·5
9383	– 2·0	– 1·7	– 2·5	–

Direction of Tilting N 30° W
Magnitude of Tilting 0.″5

We have now determined the extents of land blocks which respectively underwent a tilting as a whole. We can find another evidence of the existence of such more or less rigid land blocks in the results of the repeated levellings here. If we displace in Fig. 2, the sections B, C, D, and E in the lower curve (II—I) along the vertical axis by 3·21 cm., –0·17 cm., –2·62 cm., and –3·88 cm. respectively, we have the curve in Fig. 2 that is shown in dotted lines. The curve obtained in this way is evidently similar to the upper curve (III—II) in its form. Thus it is concluded that these land blocks were subjected to independent vertical movements simultaneously with the tilting movements. The facimile of such movements may be visualised by an aggregate of wooden blocks floating side by side on a disturbing water surface. From B.M. 9382 south down, no evidence of block movements is apparent and this is rather a striking contrast with the structure of the northern part of the levelling route, on which the evidence of block movements is so pronounced.

Results of the Levelling across the Tanna Seismic Faults.

The change of land levels along this route is shown in Fig. 7. At the time of the earthquake of Nov. 26, 1930, a system of remarkable seismic faults was produced in the northern part of the peninsula in approximately NS trend. The fault was about 30 km. in length and crossed the levelling route from B.M. 52 to B.M. 60 between the bench-marks 55 and 55.1. The land to the east of the fault was displaced northwards relative to the land to the west of it, the amount of the dislocation being about 100 cm. as measured on the surface of the ground. The new seismic fault was right along the well-known Tanna tectonic line. The vertical movement along the recent seismic fault was not simple but of a type of a hinge, the western block, relative to the eastern one being depressed at the northern part of the fault whereas elevated at the southern part. The movement in the neighbourhood of the fault was, so far as the levelling is concerned, of a V-shaped depression. It is to be noted that a movement somewhat similar to the recent one may be found in the neighbourhood of the fault in the interval between the first and second levellings which includes in it the event of the Kwantô earthquake of 1923. Prof. A. Imamura has long emphasised

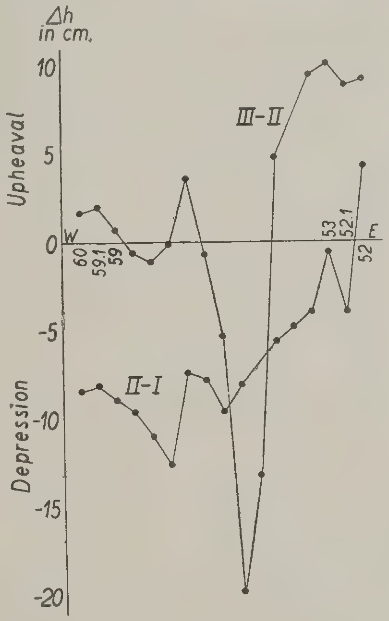

Fig. 7.
Change of Level across the Tanna Seismie Fault

that there are at least two types in the movement at a fault found by means of levelling, the one he called N-type, and the other V-type, according to the similarity in forms of the profile of the change of land levels to these characters. The present case for the Tanna fault may correspond to the category of V-type. In this route, the tilting of land blocks were also determined similarly as in the preceding chapter. The

Table IX.

Bench Marks 59.1 ; 59 ; 58.1 ; 58 ; 57.1 ;

Azimnth

From \ To	59.1	59	58.1	58	57.1
59.1	—	20°	29°	13°	−9°
59	−160°	—	40°	8°	−23°
58.1	−151°	−120°	—	−35°	−55°
58	−167°	−172°	145°	—	−69°
57.1	−171°	+157°	125°	111°	—

Inclination for (III-II) in 10^{-6}

From \ To	59.1	59	58.1	58	57.1
59.1	—	−6·1	−6·2	−6·1	−3·6
59	+6·1	—	−6·3	−6·1	−1·9
58.1	+6·2	+6·3	—	−3·0	+1·6
58	+6·1	+6·1	+3·0	—	+2·4
57.1	+3·6	+1·9	−1·6	−2·4	—

Direction of Tilting N 50° E

Magnitude of Tilting 1.″5

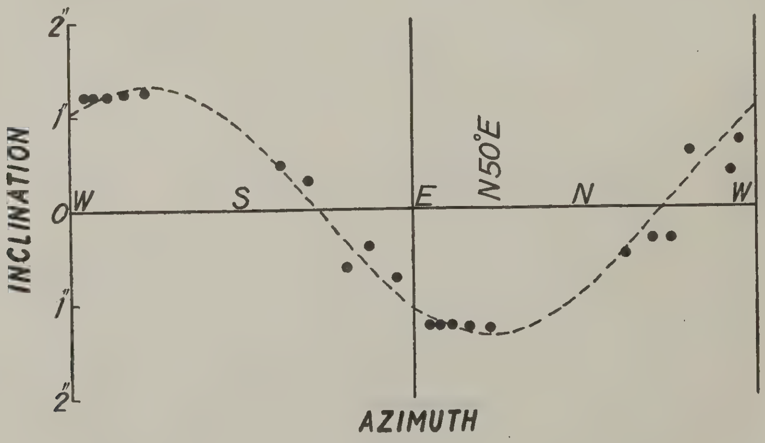

Fig. 8.

Table X.

Bench-Marks 57 ; 56.1 ; 56 ; 55.1.

Azimuth

From \ To	57	56.1	56	55.1
57	–	47°	36°	30°
56.1	−133°	–	23°	21°
56	−144°	−157°	–	18°
55.1	−150°	−159°	−162°	–

Inclination for (III-II) in 10^{-6}

From \ To	57	56.1	56	55.1
57	–	−24·4	−25·3	−45 4
56.1	+24·4	–	−27·1	−54·4
56	+25·3	+27·1	–	−78·6
55.1	+45·4	+54·4	+78·6	–

Direction of Tilting S 50° E

Magnitude of Tilting 28″

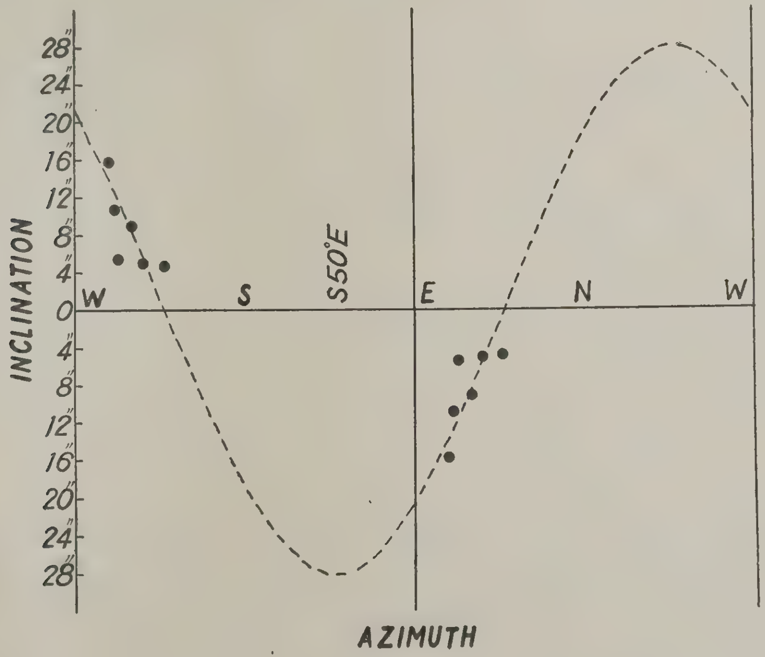

Fig. 9.

results of the calculations are shown in Tables IX and X. The results of these calculations are shown in Figs. 8 and 9.

The Results along the Eastern Coast of the Peninsula.

The change of land levels along the eastern coast of the peninsula is shown in Fig. 10. The results of the levellings along this route were already discussed in the writer's previous papers.[3] In this section it is to be noted that the movement of the earth's crust that occurred in the interval between the first and second levellings is decidedly different from what occurred in the interval between the second and third levellings.

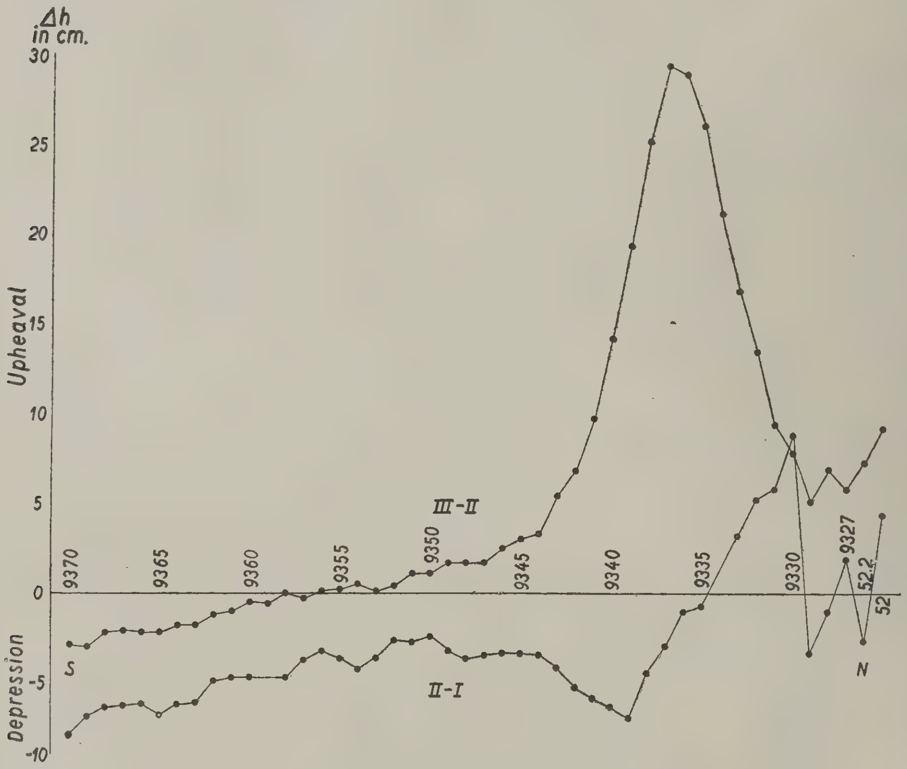

Fig. 10.

Change of Level along the Eastern Coast of Idu Peninsula.

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[3] C. TSUBOI, *Proc. Imp. Acad.*, 7 (1931), 153; *Bull. Earthq. Res Inst.*, 9 (1931), 151.

Idu Earthquake of 1930 and Tilting of Land Blocks.

The writer has often pointed out[4] the block-structure of the outer part of the earth's crust especially in earthquake districts. These individual land blocks seem to move apparently independently, yet their movements must be in some order when viewed as a whole. We have here a good example of such a case. We have determined the directions and magnitudes of tilting of land blocks in the northwestern part of the peninsula. They are shown by arrows in Fig. 11. A remarkable feature is at once apparent that the arrows change the directions clockwise as we go from the southern blocks to the northern. This shows that the land as a whole was twisted like a plate. As was described in one of the preceding chapters, the relative vertical displacement along the Tanna seismic fault was of a type of a hinge. This can be regarded now as a natural consequence of the twisting deformation of the earth's crust to the west of the fault.

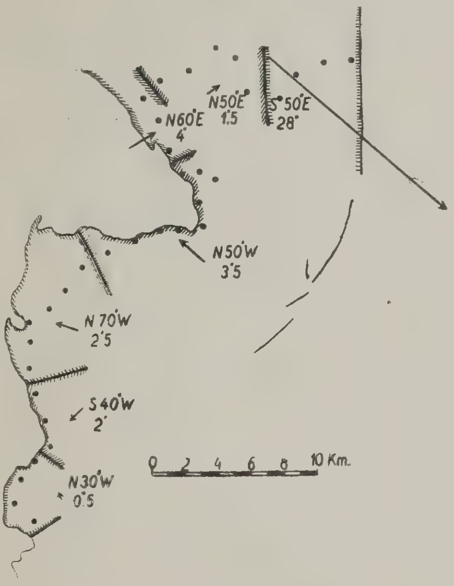

Fig. 11.

In conclusion the writer wishes to express his sincere thanks to Professor T. Terada for his interests in this work and also to Mr. N. Miyabe for his kind advices. Thanks are also due to the Land Survey Department of the Imperial Army for placing the results of the survey at our disposal.

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[4] C. Tsuboi. *Bull. Earthq, Res. Inst.*, 6 (1929), 71; 7 (1929), 103; 8 (1930), 153; *Proc. Imp. Acad.*, 4 (1928), 529.

19. 伊豆半島に於ける水準測量の結果に就いて

地震研究所 坪井忠二

伊豆半島の周圍に沿つた水準測量は既に三度も繰返されたが、此の論文は夫等の結果に就いて若干の考案を加へたものである。特に昭和五年十一月二十六日の北伊豆地震によつて生じたと信ぜらるゝ垂直變動に就いては稍詳細に吟味をなした。宮部理學士が考案した方法に從つて地塊の大きさ、傾斜の方向、及び其の量等を定めて見た。その内稍大切な結果と思はれるのは次の二點である。即ち第一は、伊豆半島西海岸北部に於いては地塊構造が著しいが、南部には之が認められないと云ふ事である。第二は伊豆半島西海岸北部に於ける地塊を全體から大きい目で見ると、大體に於いて北の方では東下りの傾斜であり、南の方では西下りの傾斜であつて、宛も此の近傍の地殼が捩れたかの如き觀を與へる事である。北伊豆地震に關聯した丹那斷層は、北方では西が東に對して相對的に沈降し、南方では反對に上昇してゐると報ぜられたが、之も斷層の西側の地殼の捩れを考へると其の自然の結果と看做す事が出來る。

20. *Movement of the Ground due to Atmospheric Disturbance in a Sea Region.*

By **Katsutada SEZAWA** and **Genrokuro NISHIMURA**,

Earthquake Research Institute.

(Read April 21, 1931.—Received June 20, 1931.)

1. In a previous paper[1] one of us studied some problem of the transmission of seismic waves on the bottom surface of an ocean and it was found that the problem is of a great importance in connection with the dispersive nature of distant earthquakes. It occurred us very recently that the problem, if somewhat extended, may also be significant on the pulsatory motion of the ground occurring in disturbed weather in a sea region. Geophysical investigations of microseisms have already been made fully by Prof. Gutenberg,[2] [3] Dr. Banerji[4] and others, chiefly by examining the data of the actual seismic records. It seems, however, that the accurate mathematical study concerning microseisms has not yet been made probably on account of the reason that the action of the water waves on the ground and on the steep coast is of a complex nature. Although it has already been concluded by Professor Gutenberg and others that the cause of the microseisms is the action of the surf against steep coasts but not the direct action of the wind pressure or of the water upon the bottom ground, yet we are now to study the problem of the movement of the ground due to the disturbed sea in rough weather for the purpose of ascertaining to what extent the change of the air pressure and also of the resulting water waves influence the microseisms in the neighbourhood of the sea.

From the result of calculation, however, it has been ascertained that even the shallow water waves give no much effect directly on the generation of microseisms and that the principal cause of those microseisms, in fact, as Professor Gutenberg[5] suggested, seems to be of a kind such as the surf at the rocky cliff of a coast.

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[1] K. Sezawa, "On the Transmission of Seismic Waves on the Bottom Surface of an Ocean," *Bull. Earthq. Res. Inst.*, 9 (1931), 115–143.

[2] B. Gutenberg, "Bodenunruhe durch Brandung und durch Frost," *ZS. Geophys.*, 4 (1928), 246–250; and a number of his papers.

[3] B. Gutenberg "Die seismische Bodenunruhe," *Gerl. Beitr. Geophys.* 11., (1912), 414.

[4] S. K. Banerji, "Microseisms Associated with Disturbed Weather in the Indian Seas," *Phil. Trans. Roy. Soc.*, 229 (1930), 287–328.

We shall assume that the horizontal surface of a sea, whose depth is h_0, is subjected to a pulsatory pressure :

$$p = f(r)e^{in_1t}, \qquad \cdots\cdots(1)$$

where r is the radial distance of a point from the pressure centre and $2\pi/n_1$ the period of the pulsation. The resulting movements of the sea water and of the surface of the solid will give us long water waves as well as microseisms of the ground caused by the atmospheric disturbance in a sea region.

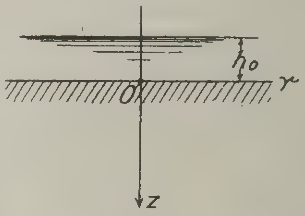

Fig. 1.

2. Referring to the axes which are shown in the figure and using the same notations as in the preceding paper,[6] we may write the expressions of the displacement of the ground and the water, besides the potential of the water waves, in the following forms :

$$\left.\begin{aligned} u_1 &= -A_m\frac{1}{h^2}\frac{\partial H_m^{(2)}(kr)}{\partial r}\,e^{-\alpha z+int}\left.\begin{matrix}\cos\\ \sin\end{matrix}\right\}m\theta, \\ v_1 &= A_m\frac{m}{h^2}\frac{H_m^{(2)}(kr)}{r}\,e^{-\alpha z+int}\left.\begin{matrix}\sin\\ -\cos\end{matrix}\right\}m\theta, \\ w_1 &= A_m\frac{\alpha}{h^2}H_m^{(2)}(kr)\,e^{-\alpha z+int}\left.\begin{matrix}\cos\\ \sin\end{matrix}\right\}m\theta, \end{aligned}\right\} \qquad \cdots\cdots(2)$$

$$\left.\begin{aligned} u_3 &= C_m\frac{\beta}{mj^2}\frac{\partial H_m^{(2)}(kr)}{\partial r}\,e^{-\beta z+int}\left.\begin{matrix}\cos\\ \sin\end{matrix}\right\}m\theta, \\ v_3 &= -C_m\frac{\beta}{j^2}\frac{H_m^{(2)}(kr)}{r}\,e^{-\beta z+int}\left.\begin{matrix}\sin\\ -\cos\end{matrix}\right\}m\theta, \\ w_3 &= -C_m\frac{k^2}{mj^2}H_m^{(2)}(kr)\,e^{-\beta z+int}\left.\begin{matrix}\cos\\ \sin\end{matrix}\right\}m\theta, \end{aligned}\right\} \qquad \cdots\cdots(3)$$

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5) B. GUTENBERG, "Microseisms in North America," *Bull. Seism. Soc. Amer.*, **21** (1931), 1–24.

6) K. SEZAWA, *loc. cit.*

$$\left.\begin{aligned}
\phi &= (D_m \operatorname{ch} k_1 z + E_m \operatorname{sh} k_1 z) J_m(kr) \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta\, e^{int},\\
u' &= \frac{i}{n}(D_m \operatorname{ch} k_1 z + E_m \operatorname{sh} k_1 z)\frac{\partial J_m(kr)}{\partial r} \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta\, e^{int},\\
v' &= -\frac{im}{n}(D_m \operatorname{ch} k_1 z + E_m \operatorname{sh} k_1 z)\frac{J_m(kr)}{r} \left.\begin{matrix}\sin\\ -\cos\end{matrix}\right\} m\theta\, e^{int},\\
w' &= \frac{ik_1}{n}(D_m \operatorname{sh} k_1 z + E_m \operatorname{ch} k_1 z) J_m(kr) \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta\, e^{int},
\end{aligned}\right\} \cdots(4)$$

where

$$k_1^2 = k^2 - \frac{n^2}{c^2}. \qquad \cdots\cdots(5)$$

The boundary conditions are such that

$$z = 0; \quad w = w', \qquad \cdots\cdots(6)$$

$$z = 0; \quad \lambda\Delta + 2\mu\frac{\partial w}{\partial z} + g(\rho - \rho')w' - \rho'\frac{\partial \phi}{\partial t} = 0, \cdots\cdots(7)$$

$$\left.\begin{aligned}
z = 0; \quad & \frac{\partial u}{\partial z} + \frac{\partial w}{\partial r} = 0,\\
& \frac{1}{r}\frac{\partial w}{\partial \theta} + \frac{\partial v}{\partial z} = 0,
\end{aligned}\right\} \cdots\cdots(8)$$

$$z = -h_0; \quad p = e^{in_1 t} f(r) \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta, \cdots\cdots(9)$$

where p is the pulsatory pressure on the surface of water.

From (8), we get

$$\frac{C_m}{m}\Big/ A_m = \frac{2\alpha j^2}{h^2(2k^2 - j^2)}. \qquad \cdots\cdots(10)$$

From (6),

$$k_1 E_m = -in\left(\frac{\alpha}{h^2}A_m - \frac{k^2}{j^2}\frac{C_m}{m}\right). \qquad \cdots\cdots(11)$$

From (7),

$$\left(\lambda - \frac{2\mu\alpha^2}{h^2}\right)A_m + \frac{2\mu k^2\beta}{mj^2}C_m + \frac{ik_1}{n}g(\rho - \rho')E_m - in\rho' D_m = 0. \cdots(12)$$

Comparing (10), (11), (12), we find

$$D_m = \frac{\mu(2k^2-j^2)^2-4\mu k^2\alpha\beta+g(\rho-\rho')\alpha j^2}{\rho' n^2\alpha j^2}\times k_1 E_m. \quad \cdots\cdots\cdots\cdots(13)$$

By the use of the relation (13), we get the equation of the pressure distribution of the sea water as follows:

$$\begin{aligned} p &= \rho'\frac{\partial\phi}{\partial t}+\rho' g w' \\ &= iE_m\times\left[\left(nk_1 \operatorname{ch} k_1 z+\frac{k_1^2 g}{n}\operatorname{sh} k_1 z\right)\right. \\ &\qquad \times\frac{(2k^2-j^2)(2\mu\alpha^2-\lambda h^2)-4\mu k^2\alpha\beta+g(\rho-\rho')\alpha j^2}{n^2\alpha j^2} \\ &\qquad \left.+\left(n\rho' \operatorname{sh} k_1 z+\frac{\rho' k_1 g}{n}\operatorname{ch} k_1 z\right)\right]\times J_m(kr)\left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta\, e^{int}. \quad \cdots\cdots\cdots(14) \end{aligned}$$

When $z=-h_0$, this may be written in the form:

$$p = XJ_m(kr)\left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta\, e^{in_1 t}, \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (15)$$

where n is equated to n_1 and

$$\begin{aligned} E_m &= \frac{X}{i\mu k_1(n_1^2-gk_1^2h_0)} \\ &\times\frac{n_1^3\alpha j^2}{\left[(2k^2-j^2)^2-4k^2\alpha\beta-\frac{g\alpha j^2}{\mu}+\frac{\rho'\alpha j^2}{\mu}\left(g-n_1^2\times\frac{g-n_1^2h_0}{n_1^2-gk_1^2h_0}\right)\right]}. \cdots(16) \end{aligned}$$

Now, write

$$F(k)\equiv(2k^2-j^2)^2-4k^2\alpha\beta-\frac{g\rho\alpha j^2}{\mu}+\frac{\rho'\alpha j^2}{\mu}\times\frac{n_1^4h_0-g^2h_0k_1^2}{n_1^2-gh_0k_1^2}, \cdots\cdots\cdots(17)$$

or, neglecting $gh_0k_1^2/n_1^2$, write

$$F(k)\equiv(2k^2-j^2)^2-4\alpha\beta k^2-\frac{g\rho j^2}{\mu}\alpha+\rho'\frac{h_0\alpha j^4}{\rho}, \quad \cdots\cdots\cdots\cdots\cdots\cdots(18)$$

then, by means of Fourier's integral expression of p on $z=-h_0$, such that

$$p = e^{in_1 t}\left\{\int_0^\infty J_m(kr)k\,dk\int_0^\infty f(\sigma)J_m(k\sigma)\sigma\,d\sigma\right\}\left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta, \cdots\cdots\cdots\cdots\cdots\cdots(19)$$

we obtain the expressions of the displacement of the water surface in the forms:

$$u'_{z=-h_0} = e^{in_1t} \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{[\{\mu(2k^2-j^2)^2-4\mu k^2\alpha\beta+g(\rho-\rho')\alpha j^2\}k_1 \operatorname{ch} k_1h_0 - n_1^2\rho'\alpha j^2 \operatorname{sh} k_1h_0]}{\rho'\mu k_1(n_1^2-gk_1^2h_0)F(k)} \frac{\partial J_m(kr)}{\partial r} kdk$$

$$\times \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma, \quad \cdots\cdots\cdots\cdots(20)$$

$$v'_{z=-h} = -e^{in_1t}\, m \left.\begin{matrix}\sin\\ -\cos\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{[\{\mu(2k^2-j^2)^2-4\mu k^2\alpha\beta+g(\rho-\rho')\alpha j^2\}k_1 \operatorname{ch} k_1h_0 - n_1^2\rho'\alpha j^2 \operatorname{sh} k_1h_0]}{\rho'\mu k_1(n_1^2-gk_1^2h_0)F(k)} \frac{J_m(kr)}{r} kdk$$

$$\times \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma, \quad \cdots\cdots\cdots\cdots(21)$$

$$w'_{z=-h_0} = e^{in_1t} \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{[\rho' n_1^2\alpha j^2 \operatorname{ch} k_1h_0 - \{\mu(2k^2-j^2)^2-4\mu k^2\alpha\beta+g(\rho-\rho')\alpha j^2\}k_1 \operatorname{sh} k_1h_0]}{\rho'\mu(n_1^2-gk_1^2h_0)F(k)} J_m(kr)kdk$$

$$\times \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma, \quad \cdots\cdots\cdots\cdots(22)$$

and similar expressions of the elastic body at the bottom surface of the sea in the forms:

$$u_{z=0} = e^{in_1t} \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{n_1^2\{(2k^2-j^2)^2-2\alpha\beta\}}{\mu(n_1^2-gk_1^2h_0)F(k)} \frac{\partial J_m(kr)}{\partial r} kdk \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma, \quad \cdots\cdots(23)$$

$$v_{z=0} = -e^{in_1t}\, m \left.\begin{matrix}\sin\\ -\cos\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{n_1^2\{(2k^2-j^2)^2-2\alpha\beta\}}{\mu(n_1^2-gk_1^2h_0)F(k)} \frac{J_m(kr)}{r} kdk \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma, \quad \cdots\cdots(24)$$

$$w_{z=0} = e^{in_1t} \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{n_1^2 \alpha j^2}{\mu(n_1^2 - gk_1^2h_0)F(k)} J_m(kr)kdk \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma. \quad \cdots\cdots\cdots\cdots(25)$$

When the depth h_0 is comparatively small, we find

$$u'_{z=-h_0} = \frac{e^{in_1t}}{\rho'\mu} \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{[\mu(2k^2-j^2)^2 - 4\mu k^2\alpha\beta + g(\rho-\rho')\alpha j^2 - \rho' n_1^2 \alpha j^2 h_0]}{(n_1^2 - gk_1^2h_0)F(k)} \frac{\partial J_m(kr)}{\partial r} kdk$$

$$\times \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma, \quad \cdots\cdots\cdots\cdots(26)$$

$$v'_{z=-h_0} = -\frac{e^{in_1t}}{\rho'\mu} m \left.\begin{matrix}\sin\\ -\cos\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{[\mu(2k^2-j^2)^2 - 4\mu k^2\alpha\beta + g(\rho-\rho')\alpha j^2 - \rho' n_1^2 \alpha j^2 h_0]}{(n_1^2 - gk_1^2h_0)F(k)} \frac{J_m(kr)}{r} kdk$$

$$\times \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma, \quad \cdots\cdots\cdots\cdots(27)$$

$$w'_{z=-h_0} = \frac{e^{in_1t}}{\rho'\mu} \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{[\rho' n_1^2 \alpha j^2 - k_1^2 h_0 \{\mu(2k^2-j^2)^2 - 4\mu k^2\alpha\beta + g(\rho-\rho')\alpha j^2\}]}{(n_1^2 - gk_1^2h_0)F(k)} J_m(kr)kdk$$

$$\times \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma, \quad \cdots\cdots\cdots\cdots(28)$$

$$u_{z=0} = \frac{e^{in_1t}n_1^2}{\mu} \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{(2k^2-j^2) - 2\alpha\beta}{(n_1^2 - gk_1^2h_0)F(k)} \frac{\partial J_m(kr)}{\partial r} kdk \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma, \quad \cdots\cdots\cdots\cdots(29)$$

$$v_{z=0} = -\frac{e^{in_1t}n_1^2}{\mu} m \left.\begin{matrix}\sin\\ -\cos\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{(2k^2-j^2)-2\alpha\beta}{(n_1^2-gk_1^2h_0)F(k)} \frac{J_m(kr)}{r} kdk \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma, \cdots\cdots\cdots\cdots (30)$$

$$w_{z=0} = \frac{e^{in_1t}n_1^2}{\mu} \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta$$

$$\times \int_0^\infty \frac{\alpha j^2}{(n_1^2-gk_1^2h_0)F(k)} J_m(kr)kdk \int_0^\infty f(\sigma)J_m(k\sigma)\sigma d\sigma. \cdots\cdots\cdots\cdots (31)$$

When the disturbed pressure is accumulated in the neighbourhood of $r=0$ and symmetrical with respect to the vertical axis passing through the pressure centre, we may have

$$m = 0; \qquad \int_0^\infty f(\sigma)2\pi\sigma d\sigma = 1, \cdots\cdots\cdots\cdots\cdots\cdots (32)$$

so that

$$\left.\begin{aligned}
u'_{z=-h_0} &= \frac{e^{in_1t}}{2\pi\rho'\mu} \\
&\times \int_0^\infty \frac{[\mu(2k^2-j^2)^2-4\mu k^2\alpha\beta+g(\rho-\rho')\alpha j^2-\rho' n_1^2\alpha j^2h_0]}{(n_1^2-gk_1^2h_0)F(k)} \frac{\partial J_0(kr)}{\partial r} kdk, \\
v'_{z=-h_0} &= 0, \\
w'_{z=-h_0} &= \frac{e^{in_1t}}{2\pi\rho'\mu} \\
&\times \int_0^\infty \frac{[\rho' n_1^2\alpha j^2-k_1^2h_0\{\mu(2k^2-j^2)^2-4\mu k^2\alpha\beta+g(\rho-\rho')\alpha j^2\}]}{(n_1^2-gk_1^2h_0)F(k)} J_0(kr)kdk,
\end{aligned}\right\} \quad (33)$$

$$\left.\begin{aligned}
u_{z=0} &= \frac{e^{in_1t}n_1^2}{2\pi\mu} \int_0^\infty \frac{(2k^2-j^2)-2\alpha\beta}{(n_1^2-gk_1^2h_0)F(k)} \frac{\partial J_0(kr)}{\partial r} kdk, \\
v_{z=0} &= 0, \\
w_{z=0} &= \frac{e^{in_1t}n_1^2}{2\pi\mu} \int_0^\infty \frac{\alpha j^2}{(n_1^2-gk_1^2h_0)F(k)} J_0(kr)kdk,
\end{aligned}\right\} \cdots\cdots\cdots (34)$$

Since we know the expression

$$J_m(kr) = -\frac{i}{\pi}\int_0^\infty \left(e^{i\left(kr\,\mathrm{ch}\,f-\frac{m\pi}{2}\right)} - e^{-i\left(kr\,\mathrm{ch}\,f-\frac{m\pi}{2}\right)}\right)\mathrm{ch}\,mfdf,^{7)} \quad \cdots\cdots\cdots(35)$$

we obtain

$$\left.\begin{aligned}
u'_{z=-h_0} &= \frac{e^{in_1t}}{2\pi^2\rho'\mu}\int_0^\infty \mathrm{ch}\,fdf \\
&\times\int_{-\infty}^\infty \frac{[\mu(2k^2-j^2)^2-4\mu k^2\alpha\beta+g(\rho-\rho')\alpha j^2-\rho' n_1^2\alpha j^2 h_0]}{(n_1^2-gk_1^2h_0)F(k)}\,e^{ikr\,\mathrm{ch}\,f}\,kdk, \\
w'_{z=-h_0} &= -\frac{ie^{in_1t}}{2\pi^2\rho'\mu}\int_0^\infty d \\
&\times\int_{-\infty}^\infty \frac{[\rho' n_1^2\alpha j^2-k_1^2h_0\{\mu(2k^2-j^2)^2-4\mu k^2\alpha\beta+g(\rho-\rho')\alpha j^2\}]}{(n_1^2-gk_1^2h_0)F(k)}\,e^{ikr\,\mathrm{ch}\,f}\,kdk,
\end{aligned}\right\} \quad (36)$$

$$\left.\begin{aligned}
u_{z=0} &= \frac{e^{in_0t}n_1^2}{2\pi^2\mu}\int_0^\infty \mathrm{ch}\,fdf\int_{-\infty}^\infty \frac{(2k^2-j^2)-2\alpha\beta}{(n_1^2-gk_1^2h_0)F(k)}\,e^{ikr\,\mathrm{ch}\,f}\,kdk, \\
w_{z=0} &= -\frac{ie^{in_1t}n_1^2}{2\pi^2\mu}\int_0^\infty df\int_{-\infty}^\infty \frac{\alpha j^2 e^{ikr\,\mathrm{ch}\,f}}{(n_1^2-gk_1^2h_0)F(k)}\,kdk.
\end{aligned}\right\} \quad (37)$$

The evaluation of the integrals of the types :

$$\int_{-\infty}^\infty \frac{[\rho' n_1^2\alpha j^2-\{\mu(2k^2-j^2)^2-4\mu k^2\alpha\beta+g(\rho-\rho')\alpha j^2\}k_1^2h_0]}{(n_1^2-gk_1^2h_0)F(k)}\,e^{ikr\,\mathrm{ch}\,f}\,kdk, \cdots(38)$$

$$\int_{-\infty}^\infty \frac{\alpha j^2\,e^{ikr\,\mathrm{ch}\,f}\,kdk}{(n_1^2-gk_1^2h_0)F(k)}, \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(39)$$

where $k_1^2 = k^2 - n_1^2/c^2$, can be performed in the following manner. Consider, for example, the integral

$$\int_c \frac{\sqrt{Z^2-h^2}\,e^{iZr\,\mathrm{ch}\,f}\,ZdZ}{\left\{n_1^2\left(\frac{c^2+gh_0}{c^2gh_0}\right)-Z^2\right\}F(Z)} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(40)$$

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7) WATSON, " Theory of Bessel Functions", (1922), 180.

taken round a contour shown in Fig. 2. In (40),

$$F(Z)=(2Z^2-j^2)^2-4Z^2\sqrt{(h^2-Z^2)(j^2-Z^2)}$$

$$-\frac{g\rho}{\mu}\sqrt{h^2-Z^2}\,j^2+\frac{\rho'\sqrt{h^2-Z^2}}{\mu}\,j^2\,\frac{n_1^4h_0-g^2h_0(Z^2-n_1^2/c^2)}{n_1^2-gh_0(Z^2-n_1^2/c^2)},\quad\cdots\cdots(41)$$

and $h^2=\rho n_1^2/(\lambda+2\mu)$, $j^2=\rho n_1^2/\mu$. $\cdots\cdots(42)$

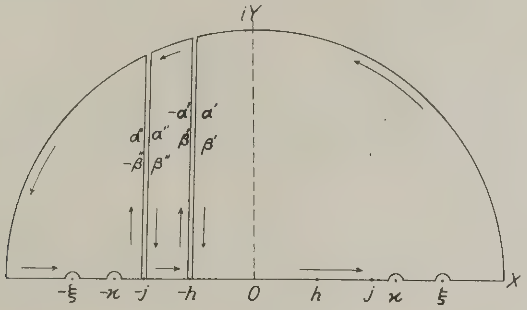

Fig. 2.

In Fig. 2, $h, j, -h, -j$ are branch points corresponding to the integrand of (40); $\pm\varkappa$ and $\pm\xi$ poles of the same integrand, namely $\pm\varkappa$ are a pair of real roots of the equation (41), while $\pm\xi$ are a pair of the roots of the equation $n_1^2\left(\frac{c^2+gh_0}{c^2gh_0}\right)-Z^2$. If we assume that there are certain terms of insensible frictional damping in the equations of the vibrations of the solid body, it will be clear that the branch points $Z=h$, $Z=j$ are shifted in the space of the lower quadrant of Fig. 2, so that these points do not influence the contour integration. The two grooves running between $(-h, 0)$, $(-h, i\infty)$ and between $(-j, 0)$, $(-j, i\infty)$ are branch lines. The positive and negative signs of $\alpha', \beta', \alpha'', \beta''$ on both sides of the lines $Z=-h$ and $Z=-j$ are taken suitably so as to satisfy the conditions of continuity. The resultant of these lines, when composed, may be equivalent to a branch line joining two points $(-h, 0)$, $(-j, 0)$. The result of the contour integral shows that

$$I=\int_{-\infty}^{\infty}\frac{\alpha j^2e^{ikr\,\mathrm{ch}\,f}\,kdk}{\left\{n_1^2\left(\frac{c^2+gh_0}{c^2gh_0}\right)-k^2\right\}F(k)}$$

$$=\frac{i4\pi\alpha_1j^2\xi}{\phi'(\xi)}\cos(\xi r\,\mathrm{ch}\,f)+\frac{i4\pi\alpha_2j^2\varkappa}{\phi'(\varkappa)}\cos(\varkappa r\,\mathrm{ch}\,f)$$

$$
+e^{-ijr\,\mathrm{ch}\,f}\int_0^\infty\left[\frac{j^2\alpha''}{\left\{n_1^2\left(\frac{c^2+gh_0}{c^2gh_0}\right)-Z^2\right\}\left\{(2Z^2-j^2)^2-4Z^2\alpha''\beta''-\frac{g\rho}{\mu}\alpha''j^2+\frac{\rho'h_0}{\rho}\alpha''j^4\right\}}\right.
$$

$$
\left.-\frac{j^2\alpha''}{\left\{n_1^2\left(\frac{c^2+gh_0}{c^2gh_0}\right)-Z^2\right\}\left\{(2Z^2-j^2)^2+4Z^2\alpha''\beta''-\frac{g\rho}{\mu}\alpha''j^2+\frac{\rho'h_0}{\rho}\alpha''j^4\right\}}\right]Ze^{-Yr\,\mathrm{ch}\,f}i\,dY
$$

$$
+e^{-ihr\,\mathrm{ch}\,f}\int_0^\infty\left[\frac{j^2\alpha'}{\left\{n_1^2\left(\frac{c^2+gh_0}{c^2gh_0}\right)-Z^2\right\}\left\{(2Z^2-j^2)^2-4Z^2\alpha'\beta'-\frac{g\rho}{\mu}\alpha'j^2+\frac{\rho'h_0}{\rho}\alpha'j^4\right\}}\right.
$$

$$
\left.+\frac{j^2\alpha'}{\left\{n_1^2\left(\frac{c^2+gh_0}{c^2gh_0}\right)-Z^2\right\}\left\{(2Z^2-j^2)^2+4Z^2\alpha'\beta'+\frac{g\rho}{\mu}\alpha'j^2-\frac{\rho'h_0}{\rho}\alpha'j^4\right\}}\right]Ze^{-Yr\,\mathrm{ch}\,f}i\,dY
$$

$$
=i\frac{4\pi\alpha_1j^2\xi}{\phi'(\xi)}\cos(\xi r\,\mathrm{ch}\,f)+i\frac{4\pi\alpha_2j^2\varkappa}{\phi'(\varkappa)}\cos(\varkappa r\,\mathrm{ch}\,f)
$$

$$
+8ie^{-ijr\,\mathrm{ch}\,f}\int_0^\infty\frac{j^2\alpha''e^{-Yr\,\mathrm{ch}\,f}\,\alpha''\beta''Z^3dY}{\left\{n_1^2\left(\frac{c^2+gh_0}{c^2gh_0}\right)-Z^2\right\}\left[\left\{(2Z^2-j^2)^2-\frac{g\rho}{\mu}\alpha''j^2-\frac{\rho'h_0}{\rho}\alpha''j^4\right\}^2-16Z^4\alpha''^2\beta''^2\right]}
$$

$$
+2ie^{-ihr\,\mathrm{ch}\,f}\int_0^\infty\frac{j^2\alpha'e^{-Yr\,\mathrm{ch}\,f}\,Z(2Z^2-j^2)^2dY}{\left\{n_1^2\left(\frac{c^2+gh_0}{c^2gh_0}\right)-Z^2\right\}\left[(2Z^2-j^2)^4-\left(4Z^2\alpha'\beta'+\frac{g\rho}{\mu}\alpha'j^2-\frac{\rho'h_0}{\rho}\alpha'j^4\right)^2\right]},
$$

$$
\cdots\cdots\cdots\cdots\cdots\cdots(43)
$$

where

$$
\alpha_1=\sqrt{\xi^2-h^2},\quad \alpha_2=\sqrt{\varkappa^2-h^2}.\quad\cdots\cdots\cdots\cdots(44)
$$

It is known that, for small values of Y,

$$
\left.\begin{aligned}
\alpha' &= -\sqrt{2hY}\,e^{-\frac{1}{4}i\pi}, & \beta' &= i\sqrt{(j^2-h^2)},\\
\alpha'' &= \sqrt{(j^2-h^2)}, & \beta'' &= -\sqrt{2jY}\,e^{-\frac{1}{4}i\pi}
\end{aligned}\right\}\quad\cdots\cdots\cdots(45)^{8)}
$$

may be taken with approximation. Hence we get

---

8) H. LAMB, *Phil. Trans. Roy. Soc.*, **203** (1904), 20.

$$I = i\frac{4\pi\alpha_1 j^2\xi}{\phi'(\xi)}\cos(\xi r\,\mathrm{ch}\,f) + i\frac{4\pi\alpha_2 j^2\varkappa}{\phi'(\varkappa)}\cos(\varkappa r\,\mathrm{ch}\,f)$$

$$-\int_0^\infty \frac{j^2(j^2-h^2)\sqrt{2jY}(-j+iY)^3 e^{-\frac{1}{4}i\pi-Yr\,\mathrm{ch}\,f}\,df}{\left\{n_1^2\frac{(c^2+gh_0)}{c^2gh_0}-(-j+iY)^2\right\}\left[\left\{(2(-j+iY)^2-j^2)^2-\frac{\rho g}{\mu}j^2\sqrt{j^2-h^2}-\frac{\rho' h_0}{\rho}j^4\sqrt{j^2-h^2}\right\}^2-32(j^2-h^2)jYe^{-\frac{i\pi}{2}}(-j+iY)^4\right]}$$

$$-\int_0^\infty \frac{\sqrt{2h}\,j^2(-h+iY)\{2(-h+iY)^2-j^2\}^2 Y^{\frac{1}{2}} e^{-\frac{1}{4}i\pi-Yr\,\mathrm{ch}\,f}\,df}{\left\{n_1^2\frac{(c^2+gh_0)}{c^2gh_0}-(-h+iY)^2\right\}\left[\{2(-h+iY)^2-j^2\}^4-2hYe^{-\frac{i\pi}{2}}\left\{4i(-h+iY)^2\sqrt{j^2-h^2}+\frac{\rho g}{\mu}j^2-\frac{\rho' h_0}{\rho}j^4\right\}^2\right]}.$$

$$\cdots\cdots\cdots\cdots(46)$$

We know again

$$\int_0^\infty Y^{1/2}\chi(Y)e^{-Yx}dY = \frac{\Pi(1/2)}{x^{3/2}}\chi(0) + \frac{\Pi(3/2)}{x^{5/2}}\frac{\chi'(0)}{1!} + \frac{\Pi(\ /2)}{x^{7/2}}\frac{\chi''(0)}{2!} + \cdots \qquad (47)^{9)}$$

Hence

$$I = \frac{i4\pi\alpha_1 j^2\xi}{\phi'(\xi)}\cos(\xi r\,\mathrm{ch}\,f) + \frac{i4\pi\alpha_2 j^2\varkappa}{\phi'(\varkappa)}\cos(\varkappa r\,\mathrm{ch}\,f)$$

$$+\frac{\Pi(1/2)}{(r\,\mathrm{ch}\,f)^{3/2}}\left[\frac{\sqrt{2j}\,(j^2-h^2)e^{-\frac{1}{4}i\pi}j^5}{\left\{n_1^2\frac{(c^2+gh_0)}{c^2gh_0}-j^2\right\}\left\{j^2-\frac{\rho g}{\mu}j^2\sqrt{j^2-h^2}-\frac{\rho' h_0}{\rho}j^4\sqrt{j^2-h^2}\right\}^2}\right] + \text{etc.}$$

$$+\frac{\Pi(1/2)}{(r\,\mathrm{ch}\,f)^{3/2}}\left[\frac{hj^2\sqrt{2h}\,e^{-\frac{1}{4}i\pi}}{\left\{n_1^2\frac{(c^2+gh_0)}{c^2gh_0}-h^2\right\}(2h^2-j^2)^2}\right] + \text{etc.} \quad \cdots\cdots\cdots(48)$$

Substituting this in (37), we obtain

---

9) H. Lamb, *loc. cit.*

$$w_{z=0} = -\frac{ie^{in_1t}n_1^2}{2\pi^2\mu g h_0}\Bigg[\frac{i4\pi\alpha_1 j^2\xi}{\phi'(\xi)}\int_0^\infty \cos(\xi r\,\mathrm{ch}\,f)df + \frac{i4\pi\alpha_2 j^2 \varkappa}{\phi'(\varkappa)}\int_0^\infty \cos(\varkappa r\,\mathrm{ch}\,f)df$$

$$+\frac{8i\Pi(1/2)(j^2-h^2)\sqrt{2j}\,j^5 e^{-\frac{i\pi}{4}}}{r^{3/2}\left\{\frac{n_1^2(c^2+gh_0)}{c^2gh_0}-j^2\right\}\left\{j^4-\frac{\rho g}{\mu}j^2\sqrt{j^2-h^2}-\frac{\rho' h_0}{\rho}j^4\sqrt{j^2-h^2}\right\}^2}\int_0^\infty \frac{e^{-ij\,\mathrm{ch}\,f}}{(\mathrm{ch}\,f)^{3/2}}df$$

$$+\frac{2i\Pi(1/2)\sqrt{2h}\,hj^2 e^{-\frac{i\pi}{4}}}{r^{3/2}\left\{\frac{n_1^2(c^2+gh_0)}{c^2gh_0}-h^2\right\}(2h^2-j^2)^2}\int_0^\infty \frac{e^{-ihr\,\mathrm{ch}\,f}}{(\mathrm{ch}\,f)^{3/2}}df\Bigg]. \quad\cdots\cdots(49)$$

The integrals of the first and second terms of the right-hand side of this expression are easily obtained by means of the formula:

$$Y_0(\xi r) = -\frac{2}{\pi}\int_0^\infty \cos(\xi r\,\mathrm{ch}\,f)df. \cdots\cdots(50)$$

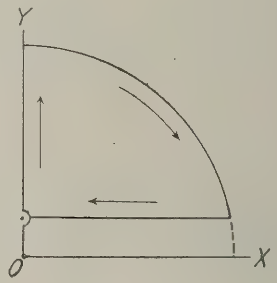

Fig. 3.

To evaluate the third and fourth integrals, we consider

$$K = \int_c \frac{e^{-\xi Z}dZ}{Z^{3/2}\sqrt{1+Z^2}} \quad\cdots\cdots(51)$$

taken round the contour shown in this page. Thus we know

$$\int_0^\infty \frac{e^{i\xi\,\mathrm{ch}\,f}}{(\mathrm{ch}\,f)^{3/2}}df = e^{-i(\xi+\frac{\pi}{4})}\sqrt{\frac{\pi}{2\xi}}\left(1+\frac{7}{4}i\frac{1}{2\xi}-\frac{15}{8}\frac{1\cdot 3}{4\xi^2}+\cdots\cdots\right). \quad (52)$$

Substituting from (50), (52) in (49), we get

$$w_{z=0} = \frac{ie^{in_1t}n_1^2}{2\pi^2 u g h_0}\Bigg[\frac{i2\pi^2\alpha_1 j^2\xi}{\phi'(\xi)}Y_0(\xi r) + \frac{i2\pi^2\alpha_2 j^2\varkappa}{\phi'(\varkappa)}Y_0(\varkappa r)$$

$$-\frac{4i\pi(j^2-h^2)j\,e^{-i(jr+\frac{\pi}{2})}}{r^2\left\{\frac{n_1^2(c^2+gh_0)}{c^2gh_0}-j^2\right\}\left\{j^2-\frac{\rho g}{\mu}\sqrt{j^2-h^2}-\frac{\rho' h_0}{\rho}j^2\sqrt{j^2-h^2}\right\}^2}$$

$$-\frac{\pi hj^2 e^{-i(hr+\frac{\pi}{2})}}{r^2\left\{\frac{n_1^2(c^2+gh_0)}{c^2gh_0}-h^2\right\}(2h^2-j^2)^2}+\cdots\cdots\Bigg]. \quad\cdots\cdots(53)$$

This expression is suitable to the problem of transmission of waves of finite extent of disturbances. To get progressive waves of an infinite extent, we add to this expression other systems of standing vibrations corresponding to the water waves as well as the surface waves of the elastic solid body, the wave lengths and the amplitudes of both systems being respectively equal to the first and the second terms of the right-hand side of the equation (53), but the phases of the additive systems differ from the original ones about $\pi/2$. The final solution is thus expressed by

$$w_{z=0} \approx -\frac{ie^{in_1t}n_1^2}{2\mu gh_0}\Bigg[\frac{\alpha_1 j^2\xi}{\phi'(\xi)}H_0^{(2)}(\xi r)+\frac{\alpha_2 j^2\chi}{\phi'(\chi)}H_0^{(2)}(\chi r)$$

$$+\frac{4i(j^2-h^2)je^{-i\left(jr+\frac{\pi}{4}\right)}}{\pi r^2\left\{\frac{n_1^2(c^2+gh_0)}{c^2gh_0}-j^2\right\}\left\{j^2-\frac{\rho g}{\mu}\sqrt{j^2-h^2}-\frac{\rho' h_0}{\rho}j^2\sqrt{j^2-h^2}\right\}^2}$$

$$+\frac{ihj^2e^{-i\left(hr+\frac{\pi}{2}\right)}}{\pi r^2\left\{n_1^2\frac{(c^2+gh_0)}{c^2gh_0}-h^2\right\}(2h^2-j^2)^2}\Bigg], \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots(54)$$

provided

$$\phi(k)=\left\{\frac{n_1^2(c^2+gh_0)}{c^2gh_0}-k^2\right\}\left\{(2k^2-j^2)^2-4\alpha\beta k^2-\frac{g\rho}{\mu}\alpha j^2+\frac{\rho' h_0}{\rho}\alpha j^4\right\}. \quad \cdots(55)$$

In the same manner of mathematical treatment we get the horizontal component of displacement of the surface of the solid, $u_{z=0}$, the similar component of the surface of water, $w'_{z=-h_0}$, and the vertical component of the surface displacement of the water, $w_{z=-h_0}$, as in the following forms:

$$u_{z=0} \approx \frac{ie^{in_1t}n_1^2}{2\mu gh_0}\left[\frac{(2\xi^2-j^2-2\alpha_1\beta_1)\xi^2}{\phi'(\xi)}H_1^{(2)}(\xi r)+\frac{(2\chi^2-j^2-2\alpha_2\beta_2)\chi^2}{\phi'(\chi)}H_1^{(2)}(\chi r)\right], \quad (56)$$

$$u'_{z=-h_3} \approx \frac{ie^{in_1t}}{2\rho'\mu gh_0}\Bigg[\frac{\{\mu(2\xi^2-j^2)^2-4\mu\xi^2\alpha_1\beta_1+g(\rho-\rho')\alpha_1 j^2-\rho' n_1^2\alpha_1 j^2h_0\}\xi^2}{\phi'(\xi)}H_1^{(2)}(\xi r)$$

$$+\frac{\{\mu(2\chi^2-j^2)^2-4\mu\chi^2\alpha_2\beta_2+g(\rho-\rho')\alpha_2 j^2-\rho' n_1^2\alpha_2 j^2h_0\}\chi^2}{\phi'(\chi)}H_1^{(2)}(\chi r)\Bigg], \cdots\cdots(57)$$

$$w'_{z=-h_0} \approx -\frac{ie^{in_1t}}{2\rho'\mu g h_0}$$

$$\times\left[\frac{\left\{\rho' n_1^2\alpha_1\mathfrak{f}^2-\left[\mu(2\xi^2-\mathfrak{f}^2)^2-4\mu\xi^2\alpha_1\beta_1+g(\rho-\rho')\alpha_1\mathfrak{f}^2\right]\left(\xi^2-\frac{n_1^2}{c^2}\right)h_0\right\}\xi}{\phi'(\xi)}H_0^{(2)}(\xi r)\right.$$

$$\left.+\frac{\left\{\rho' n_1^2\alpha_2\mathfrak{f}^2-\left[\mu(2\varkappa^2-\mathfrak{f}^2)^2-4\mu\varkappa^2\alpha_2\beta_2+g(\rho-\rho')\alpha_2\mathfrak{f}^2\right]\left(\varkappa^2-\frac{n_1^2}{c^2}\right)h_0\right\}\varkappa}{\phi'(\varkappa)}H_0^{(2)}(\varkappa r)\right] \quad \cdots\cdots(58)$$

in which

$$\beta_1=\sqrt{\xi^2-\mathfrak{f}^2}, \quad \beta_2=\sqrt{\varkappa^2-\mathfrak{f}^2}, \quad \cdots\cdots(59)$$

and the terms corresponding to the dilatational and the distortional waves are neglected.

3. It may be seen from (54) (or other expressions) that the movement of the solid body (or of water) is composed of four kinds of displacements, namely the displacement due to the transmission of shallow water waves, that due to Rayleigh-waves on the bottom surface of the water superposed upon a solid body, that due to distortional waves through the body and also that due to dilatational waves through the same body. The velocities of transmission of the waves of these displacements are, of course, equal to those peculiar to the respective kinds of waves. Thus the velocity of transmission of the waves of the displacement of the solid due to the shallow water waves is exceedingly slow in comparison with that of the Rayleigh-type deformation.

The amplitudes of the deformation of the solid body due to Rayleigh-waves and also to the shallow water waves change as inverse square root of the epicentral distance, while those due to the dilatational and distortional waves diminish as inverse square of the epicentral distance, so that it may be concluded that the principal movement at a certain distance from the centre of the pulsating pressure should be caused by the transmission of Rayleigh-waves as well as shallow water waves.

It is important to know the relative magnitudes of the deformations of the solid due to the transmission of shallow water waves and to that of Rayleigh-type waves, because it is yet uncertain, whether the microseisms occurring in a disturbed weather may be the effect of the seismic waves transmitted directly from the region of the original disturbance, or may be the vibratory motion of the ground due to the disturbed water waves approaching from the origin to the locality of the observing station, or even due to some other cause such as the surf against the steep coast.

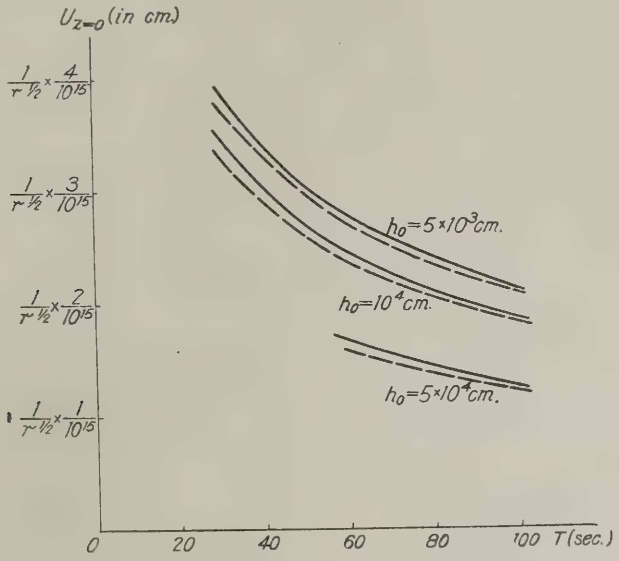

Fig. 4. (r in cm.)

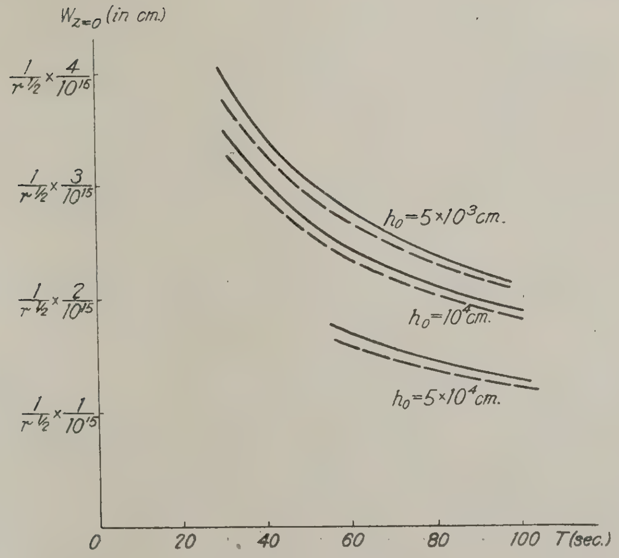

Fig. 5. (r in cm.)

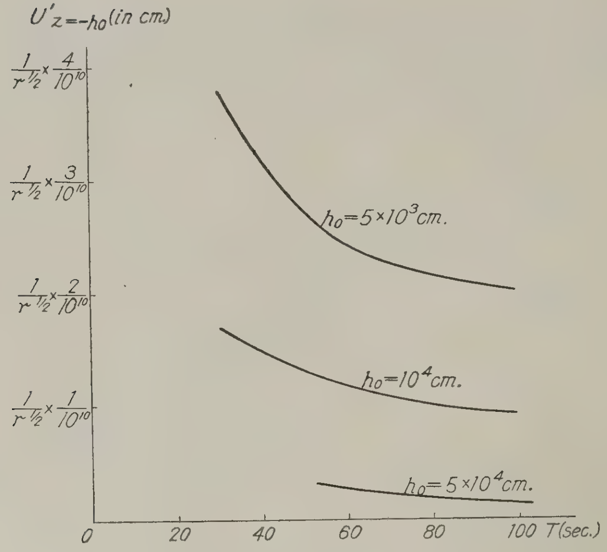

Fig. 6. (r in cm.)

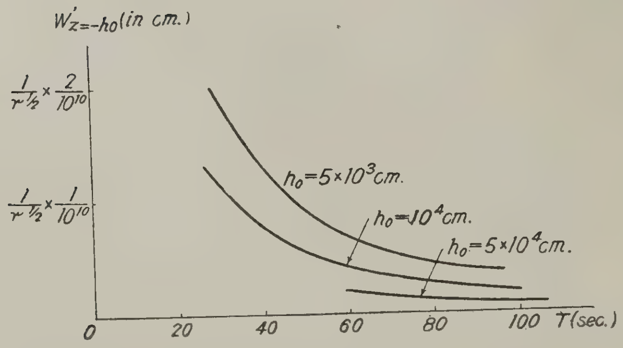

Fig. 7. (r in cm.)

Assuming $g=980$, $c^2=2{\cdot}045\times10^{10}$, $\rho'=1{\cdot}0$, $\rho=2{\cdot}5$, $\mu/\rho=3{\cdot}14^2\times10^{10}$ in C.G.S. unit, we have calculated the magnitudes of $u_{z=0}$, $w_{z=0}$, $u'_{z=-h_0}$, $w'_{z=-h_0}$ for different values of $T(=2\pi/n_1)$ and h_0. The results are plotted in Figs. 4, 5, 6, 7. The ordinates of the broken line from the base gives the effect due to the term involving $H_0^{(2)}(\xi r)$ and the vertical distance between the full line and this broken line indicates the effect due to the term containing $H_0^{(2)}(\varkappa r)$. In Figs. 6 and 7 the broken line coincides practically with the full line. The former cause, however, is principally of statical and special to shallow water, so that this is not yet sufficient for the full explanation of the microseisms. From these figures it will be clearly seen that the microseisms are rather due to long water waves near the observing station which are transmitted from the region of the disturbed weather, but not due to the seismic waves directly transmitted from such a region. Dr. Banerji[10] seemed to have the similar opinion. It is also to be noticed that the amplitude of the ground due to pulsatory original disturbance of long periods is smaller than that due to the disturbance of short periods, even though the amplitude of the disturbing pressure is kept constant. As Professor Gutenberg[11] suggested, this only fact is in good accordance with the phenomenon that the breakers play an important *rôle* on the microseisms of short periods. In fact, the pulsatory motion observed at a station seems partly to be the radiation, in the neighbourhood of a coast, of the deformation of the ground, which is transmitted with the velocity of long water waves. Besides the action of the surf against a steep coast, some portion of the shock of the breakers themselves must also be contributed from these radiated waves. The radiation of the deformation of the bottom ground and that of the shock due to breakers may be combined in certain cases owing to their approximately simultaneous radiation at the coast. Again, the comparison of Figs. 4, 5 and Figs 6, 7 shows that the displacement of the surface of the water is greater than that of the surface of the bottom ground about 10^4 times. Although it is obvious that the amplitude of water waves is exceedingly large in comparison with that of the ground, yet we may get some knowledge on the order of its magnitude from the result of the present calculation. It is, however, understood that the deformation of the bottom ground never corresponds with the statical head of the wave height. This reason will clearly be seen from the elementary theory of hydrodynamics with respect to the wave motion. The analytical treatment of the fact that the radiation of the deformation of the bottom ground due to the shallow water waves is still small compared with the shock of the surf against a steep coast, will be published in a future paper.

Summary.

We may now complete this paper with a brief summary.

1. The movement of the ground is composed of four kinds of displacements; namely the displacement due to the transmission of

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[10] S.K. Banerji, *loc. cit.*

[11] B. Gutenberg, *loc. cit.*

shallow water waves, that due to Rayleigh-waves, that due to distortional waves and that due to dilatational waves.

2. The velocity of the transmission of the displacement of the body due to shallow water waves is equal to that of shallow water waves, while the transmission of the displacements of other kinds have their own velocities peculiar to the respective waves.

3. The amplitudes of the deformation of the solid body due to Rayleigh-waves and also to shallow water waves change as inverse square root of the epicentral distance, while those due to the dilatational and distortional waves diminish as inverse square of the epicentral distance.

4. Microseisms due to a disturbed weather occurring in a different region are chiefly due to long water waves, including breakers at the coast, advancing near the observing station, but not the seismic waves directly transmitted from the region of the disturbed weather. The action of the long water waves is, however, relatively small compared with that of breakers.

5. The amplitude of the ground due to pulsatory original disturbance of long periods is smaller than that due to short periods, even though the amplitude of the disturbing pressure is kept constant.

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20. 海面大氣壓の擾亂によつて起る地動に就て

地震研究所 {妹澤克惟
西村源六郎

遠方の洋上に低氣壓が起つてゐる時、たとひ觀測點の附近は平穩であつても、地震計に脈動がよく現はれるといふ事が既に知られて居る。しかし其脈動は低氣壓の中心地方から直接地震波として來たものであるか、又は擾亂が一度海洋波として送られて來てから後其附近の海岸に於て地動に變化したものか未だ充分わかつて居らぬ樣に思はれる。

その機構を確める目的を以て筆者等は、半無限固體上に水の層を置き、其水面に適當な分布をなす氣壓の週期的變化を與へた場合に生ずる水の波と固體の變形とを計算し、脈動に對して如何なる原因をなすべきかを考へて見たのである。勿論この氣壓の週期的變化といふ事は、實際にはもつと複雜なものを簡單な形で代表させたまでである。

計算の結果によれば、固體の動き方は四種類の變位から成り、第一のものは淺海波の傳播によつて與へられる影響であつて其傳はる速さは恰度其淺海波の速度に等しいのである。第二のものはレーリー波の速度を以て傳はる固體其自身の波であり、他の二種は夫々固體の縱波と橫波とである。

淺海波に伴つて起る波動とレーリー波に相當する波動とは擾亂氣壓の中心からの距離の平方根に反比例して振幅が減じて行く。然るに縱波と横波とは距離の二乘に反比例して振幅が少くなる。從て脈動が縱波や横波に基くものでない事は明である。

次に原點からのレーリー波による土地の振幅は、淺海波に伴つて起る振幅に比較する時は非常に小さい。從て脈動は原點から擾亂が一度淺海波として送られ、其に相當する土地の變形が傳はる事及び淺海波が海岸で碎けて生ずる振動とが非常に勢力のある原因をなす事がわかるのである。しかしこの論文では淺海波が碎けて斷崖などに直接衝動を與へる場合は態と避けた。これが主要な原因である事は明であるけれども餘りわかり切つた現象であるからである。實は淺海波による土地の變形が共儘傳播する事と淺海波が海岸で碎けて生ずる振動とは其生成の時間が大體同じである爲に之を分離する事は殆ど不可能といつても差支がない。しかし兩方とも同じ種類の原因であるから强ひて分る必要もないと思ふ。

倘大氣壓の擾亂振幅が同じでも、擾亂振動の週期が短いもの程土地の振幅卽ち脈動の振幅が大になる事は注意を要する事と思ふ。

21. *A Kind of Waves transmitted over a Semi-infinite Solid Body of Varying Elasticity.*

By **Katsutada SEZAWA**,

Earthquake Research Institute.

(Read July 5, 1927 and April 21, 1931.—Received June 20, 1931.)

In this paper I am going to study the propagation of surface waves over a semi-infinite solid body whose elastic constants are functions of the position of a material point of the body below its free surface. There are, of course, several kinds of waves according with the forms of the functions of varying elasticities and also with the types of the propagated waves; yet we now confine ourselves to the case such that

$$\Delta = 0, \qquad w = 0; \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(1)$$

$$\mu = c(d+z_1), \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(2)$$

where Δ is the dilation, w the vertical component of the displacement, μ the modulus of rigidity, and z_1 the depth of a material point below the free surface, c and d being certain constants. Although a similar kind of waves has already been dealt with by MEISSNER[1] and AICHI,[2] yet their cases belong to a one-dimensional problem and the methods of integration of differential equation are quite different from that of the present paper.

The differential equation of motion of a semi-infinite solid body, when the conditions in (1) are to be satisfied, are expressed by

$$\rho\frac{\partial^2 u}{\partial t^2} = -\frac{2\mu}{r}\frac{\partial \varpi_z}{\partial \theta} + 2\frac{\partial(\mu\varpi_\theta)}{\partial z}, \quad \cdots\cdots\cdots\cdots\cdots(3)$$

$$\rho\frac{\partial^2 v}{\partial t^2} = -2\frac{\partial(\mu\varpi_r)}{\partial z} + 2\mu\frac{\partial \varpi_z}{\partial r}, \quad \cdots\cdots\cdots\cdots\cdots(3)$$

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[1] E. MEISSNER, "Elastische Oberflächen-Querwellen," *Verh. 2. int. Kongr. f. tech. Mech.*, (Zürich, 1926), 3-11; and also *Vierteljahr. Nat. Forsch. Ges.*, Zürich, 67 (1921), 181.

[2] K. AICHI, "On the Transversal Seismic Waves travelling upon the Surface of Heterogeneous Material," *Proc. Phys.-Math. Soc.*, Japan, [3], 4 (1922), 137-142.

provided

$$2\varpi_r = -\frac{\partial v}{\partial z},\ 2\varpi_\theta = \frac{\partial u}{\partial z},\ 2\varpi_z = \frac{1}{r}\left(\frac{\partial(rv)}{\partial r} - \frac{\partial u}{\partial \theta}\right), \quad (4)$$

in which ρ is the density of the solid and u, v are the radial and azimuthal components of the displacement. From the condition of the problem we have the identical relation such that

$$\frac{1}{r}\,\frac{\partial(ru)}{\partial r} + \frac{1}{r}\,\frac{\partial v}{\partial \theta} = 0. \quad \cdots\cdots(5)$$

Eliminating u, v between (3) and (4), we obtain

$$\rho\frac{\partial^2 \varpi_z}{\partial t^2} = \mu\left(\frac{\partial^2 \varpi_z}{\partial r^2} + \frac{1}{r}\,\frac{\partial \varpi_z}{\partial r} + \frac{1}{r^2}\,\frac{\partial^2 \varpi_z}{\partial \theta^2}\right) + \frac{\partial}{\partial z}\,\mu\frac{\partial \varpi_z}{\partial z}, \quad \cdots(7)$$

$$\rho\frac{\partial^2 \varpi_r}{\partial t^2} = \frac{\partial^2}{\partial z^2}\left(\mu\,\varpi_r\right) - \frac{\partial}{\partial z}\left(\mu\frac{\partial \varpi_z}{\partial r}\right), \quad \cdots\cdots(8)$$

$$\rho\frac{\partial^2 \varpi_\theta}{\partial t^2} = \frac{\partial^2}{\partial z^2}\left(\mu\,\varpi_\theta\right) - \frac{1}{r}\,\frac{\partial}{\partial z}\left(\mu\frac{\partial \varpi_z}{\partial \theta}\right). \quad \cdots\cdots(9)$$

These differential equations are satisfied by

$$\varpi_z = B_m \Phi(z) H_m^{(2)}(kr) \left.\begin{matrix}\sin\\ -\cos\end{matrix}\right\} m\theta e^{ipt}, \quad \cdots\cdots(10)$$

$$\varpi_r = \frac{B_m}{k^2}\,\frac{\partial \Phi(z)}{\partial z}\,\frac{\partial H_m^{(2)}(kr)}{\partial r} \left.\begin{matrix}\sin\\ -\cos\end{matrix}\right\} m\theta e^{ipt}, \quad \cdots\cdots(11)$$

$$\varpi_\theta = \frac{B_m m}{k^2}\,\frac{\partial \Phi(z)}{\partial z}\,\frac{H_m^{(2)}(kr)}{r} \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\} m\theta e^{ipt}, \quad \cdots\cdots(12)$$

where p is frequency of waves, $2\pi/k$ wave length, B_m a constant and $\Phi(z)$ is a certain function which satisfies the differential equation

$$\frac{d^2\Phi(z)}{dz^2} + \frac{1}{\mu}\,\frac{d\mu}{dz}\,\frac{d\Phi(z)}{dz} + \left(\frac{\rho p^2}{\mu} - k^2\right)\Phi(z) = 0. \quad \cdots\cdots(13)$$

The components of the displacement $(u,\ v)$ are found from (4) in the following forms:

$$u = 2B_m \frac{m}{k^2} \Phi(z) \frac{H_m^{(2)}(kr)}{r} \left.\begin{matrix}\cos \\ \sin\end{matrix}\right\} m\theta e^{ipt}, \cdots\cdots\cdots\cdots (14)$$

$$v = -2B_m \frac{1}{k^2} \Phi(z) \frac{\partial H_m^{(2)}(kr)}{\partial r} \left.\begin{matrix}\sin \\ -\cos\end{matrix}\right\} m\theta e^{ipt}, \cdots\cdots\cdots (15)$$

When z is taken vertically downwards and $z = d$ is assumed to be the free surface, the boundary conditions at that surface are written by

$$z = d: \left\{\begin{array}{ll} \lambda\Delta + 2\mu\dfrac{\partial w}{\partial z} = 0, & \cdots\cdots\cdots\cdots (16) \\ \dfrac{1}{r}\dfrac{\partial w}{\partial \theta} + \dfrac{\partial v}{\partial z} = 0, & \cdots\cdots\cdots\cdots (17) \\ \dfrac{\partial w}{\partial r} + \dfrac{\partial u}{\partial z} = 0. & \cdots\cdots\cdots\cdots (18) \end{array}\right.$$

From the nature of the problem, (16) is identically satisfied, and (17) and (18) are simply written by

$$z = d: \qquad \frac{\partial v}{\partial z} = 0, \qquad \frac{\partial u}{\partial z} = 0; \cdots\cdots\cdots\cdots (19)$$

and therefore

$$\left[\frac{d\Phi(z)}{dz}\right]_{z=d} = 0 \cdots\cdots\cdots\cdots (20)$$

is the only condition of the boundary.

When the distribution of the elastic constants is defined by (2), i.e.

$$\mu = cz \qquad (z = d + z_1), \cdots\cdots\cdots\cdots (2')$$

the equation (13) can be transformed to

$$z\frac{d^2\Phi(z)}{dz^2} + \frac{d\Phi(z)}{dz} + \left(\frac{\rho p^2}{c} - k^2 z\right)\Phi(z) = 0. \cdots\cdots\cdots\cdots (21)$$

Putting

$$\Phi(z) = e^{kz}\,\Phi_1(z), \cdots\cdots\cdots\cdots (22)$$

we get

$$z\frac{\Phi_1^2(z)}{dz^2} + (1 + 2kz)\frac{d\Phi_1(z)}{dz} + k\left(1 + \frac{\rho p^2}{kc}\right)\Phi_1(z) = 0. \cdots\cdots (23)$$

Writing

$$1+\frac{\rho p^2}{kc}=2\alpha, \quad\cdots\cdots\cdots\cdots(24)$$

the appropriate solution of (23) is expressed by

$$\begin{aligned}\Phi_1(z) &= \left\{1-\frac{\alpha}{1.1}(2kz)+\frac{\alpha(\alpha+1)}{1.2.1.2}(2kz)^2-\cdots\cdots\right\}\\ &= {}_1F_1(\alpha\,;\ 1\,;-2kz). \quad\cdots\cdots\cdots\cdots(25)^{3)}\end{aligned}$$

Substituting (22) and (25) in (20), we have

$$\frac{d}{dz}\Big[e^{kz}\,{}_1F_1(\alpha\,;\ 1\,;-2kz)\Big]_{z=d}=0, \quad\cdots\cdots\cdots\cdots(26)$$

which is to be written by

$$\frac{d_1F_1(\alpha\,;\ 1\,;-2kz)}{dz}+k\,{}_1F_1(\alpha\,;\ 1\,;-2kz)=0 \quad\cdots\cdots\cdots(27)$$

at $z=d$.

When kd is very small, the solution of (27) is approximately expressed by

$$2\alpha=1. \quad\cdots\cdots\cdots\cdots(28)$$

The second approximation gives us

$$2\alpha=1+\frac{1}{2}(kd). \quad\cdots\cdots\cdots\cdots(29)$$

The third approximation shows that

$$2\alpha=1+\frac{1}{2}(kd)+0. \quad\cdots\cdots\cdots\cdots(30)$$

The fourth approximation gives us

$$2\alpha=1+\frac{1}{2}(kd)-\frac{1}{48}(kd).^3 \quad\cdots\cdots\cdots\cdots(31)$$

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[3] E. W. Barnes, *Camb. Trans.*, 20, 253: H. Lamb, *Proc. Roy. Soc.*, London, 86 (1911), 551.

From (24) and (31), we obtain

$$\left(\frac{p}{k}\right)^2 = (2\alpha-1)\frac{1}{k}\,\frac{c}{\rho}$$

$$=\frac{1}{2}\left\{1-\frac{1}{24}(kd)^2\right\}\frac{cd}{\rho}\,. \quad\cdots\cdots\cdots\cdots\cdots(32)$$

If we write the modulus of rigidity at the free surface by $\mu_0(=cd)$, we have

$$\text{Velocity of propagation} = \sqrt{\frac{1}{2}\left\{1-\frac{1}{24}(kd)^2\right\}}\sqrt{\frac{\mu_0}{\rho}}\,,\cdots\cdots\cdots(33)$$

the calculated results being shown in the table below:

kd	0	0·1	0·5	1·0	1·5
Velocity $\Big/\sqrt{\frac{\mu_0}{\rho}}$	0·713	0·713	0·708	0·696	0·679

The components of the displacement are written by

$$\left.\begin{aligned} u &= 2B_m\frac{m}{k^2}e^{kz}{}_1F_1(\alpha\,;\ 1\,;-2kz)\frac{H_m^{(2)}(kr)}{r}\ \left.\begin{matrix}\cos\\ \sin\end{matrix}\right\}m\theta e^{ipt},\\ v &= -2B_m\frac{1}{k^2}e^{kz}{}_1F_1(\alpha\,:\ 1\,;-2kz)\frac{\partial H_m^{(2)}(kr)}{\partial r}\ \left.\begin{matrix}\sin\\ -\cos\end{matrix}\right\}m\theta e^{ipt}.\end{aligned}\right\}\cdots(34)$$

In some cases, we have

$$e^{kz}{}_1F_1(\alpha\,;\ 1\,;-2kz)\to 0 \qquad (35)$$

as $z\to\infty$, on account of the reason that, in such cases, the value of ${}_1F_1(\alpha;\ 1;-2kz)$ decays more quickly than that of e^{-kz} as z is increased continuously. Thus the waves written by (34) may have the characteristic of surface waves.

From the expression of (35) it may be noticed that the radial component of the displacement of the waves of the present type quickly disappears as the waves proceed outwards from the epicentre, while the transverse component is transmitted in the manner of the ordinary Love-waves, the azimuthal distribution of the azimuthal displacement being maintained for all radius. It may no doubt be significant on seimology that this kind of waves, in which the vertical displacement and the dilatation do not exist, and the velocity of propagation is different for different wave length, is possible to be transmitted over the free surface whose elastic constant increases continuously along the depth of the body.

21. 彈性が深さに從て變る半無限固體上に傳はる一地震波

地震研究所 妹澤克惟

半無限固體の彈性が其表面からの深さに從て變化する場合に其ダイレテーションと上下の變位とが零になる樣な場合に一種の地震波の存在し得る事を確めた。多少似た場合の研究はマイスナーや愛知博士などによつても行はれて居るけれども、其等は一次元的の問題であり、且つ一般の微分方程式の積分の方法などに於ても可なり違つて居る。さて地震波の性質をよくしらべて見ると波動の進行方向の變位は震央からの距動が遠くなるに從つて急に少くなるけれども、其方向に直角な向の水平變位はそれ程減少せず、普通の二次元傳播の法則に從つて居る事がわかる。又其樣な横變位は震央からの距離に無關係に其割合が保持される事が示されて居る。波動の速度は波長が長くなる程多少は速くなるとはいへ、それ程大きくはならぬ樣である。一體ラブ波の如く違つた物質から成る表面層を特別に置かなくても物質が連續的に變化しさへすればラブ波に似た波の存在し得る事は驗震學上無意味の事とは思はれぬ次第である。

22. *Un sismographe accélérométrique et ses enregistrements*

par **Mishio Ishimoto,**

Institut de Recherches sur les Tremblements de terre.

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1. Introduction.

On sait que les accélérations des secousses sismiques ont un rapport étroit avec les catastrophes; mais les enregistrements accélérométriques des secousses ne sont pas encore réalisés de manière permanente dans les observations sismiques. Actuellement, les estimations de la valeur de l'accélération sont faites suivant le degré de destruction des bâtiments ou de glissement des pierres dans les cimetières.

Les deux ou trois procédés existant pour la mesure directe des accélérations sismiques, ne nous semblent pas encore bien au point pour les observations permanentes. Nous avons déjà publié une étude[1] préliminaire sur la valeur accélérométrique des secousses ainsi que les caractéristiques des ondes ; dans ce cas-là ils sont fait avec des enregistrements optiques. Comme nous l'avons signalé dans ce mémoire, ce procédé d'enregistrement n' a pas été trouvé très commode pour continuer nos observations, d'une part parce qu'il est très couteux et d'autre part parce que les courbes enregistrés ne sont pas assez fines.

Pour enregister les accélérations dans les secousses sismiques, on considère habituellement le déplacement d'une masse d'un système vibratoire dont la période propre est assez courte par rapport à celle de secousses à étudier. On amplifie suffisamment ce déplacement pour apercevoir le passage des secousses enregistrées sur un tambour tournant. L'équation du mouvement sera :

$$M\ddot{y} + 2\varepsilon\dot{y} + ky = -M\ddot{x}, \quad \cdots\cdots\cdots\cdots\cdots\cdots(1)$$

où y est le déplacement relatif de M par rapport au sol et x le déplacement du sol par rapport à l'espace. Posons dans (1) $\frac{2\varepsilon}{M} = 2\lambda$, $\frac{k}{M} = n^2$, et $x = a \sin pt$, on aura

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[1] M. Ishimoto, *Bull. Earthq. Res. Inst.*, 9 (1931), 159.

$$\ddot{y} + 2\lambda\dot{y} + n^2 y = ap^2 \sin pt, \cdots\cdots\cdots\cdots(2)$$

et on obtient la solution

$$y = \frac{ap^2 \sin(pt-\delta)}{\sqrt{(n^2-p^2)^2+4\lambda^2p^2}} + \text{terme d'oscillation propre.} \cdots(3)$$

Considérons le cas où n est très grand par rapport à p, on a

$$y = \frac{ap^2}{n^2} \sin pt, \cdots\cdots\cdots\cdots(4)$$

qui nous montre que le déplacement de la masse est proportionnel à la valeur de l'accélération. Cependant comme ce déplacement reste toujours assez petit, on est obligé choisir un procédé qui poura enregistrer de manière visible les secousses sismiques. Par conséquent il semblait très difficille d'enregistrer les accélérations des secousses par un procédé purement mécanique. Pour cela on utilise le phénomène piézo-électrique ou le changement de capacité électrique d'un diaphragrame métallique bien tendu : mais ces procédés se heurtent toujours à la difficulté de maintenir les appareils dans des conditions favorables aux observations permanentes.

Pour réaliser un sismographe accélérométrique, on remarque d'une part qu'il n'y a presque plus d'ondes sismiques de période inférieure à 0·2 seconde et d'autre part que les ondes sismiques de petite période ne jouent pas un rôle important sur la destruction des bâtiments. Autrement dit, la valeur de l'accélération n'est importante qu'autant que sa période d'oscillation demeure assez longue par rapport à celle des maisons et dans ce cas l'action des secousses sismiques est considéré comme une force statique.

Considérant ces conditions réelles, on peut alors fixer la période propre de l'appareil **à** 0·15 seconde, période inférieure à celles des secousses sismiques. Quant à la sensibilité de l'appareil, il nous semble qu'il est suffisant d'avoir 1 mm de déplacement à l'extrémité de la plume pour 1 gal d'accélération. Désignons par ξ_m le déplacement maximum de la pointe correspondant à l'accélération $-A \sin pt$ du sol, par T_0 la période d'oscillation propre de l'appareil et par R le rapport d'amplification géométrique ; on a la relation :

$$\xi_m = \frac{T_0^2}{4\pi^2} A{\cdot}R. \cdots\cdots\cdots\cdots(5)$$

Posons $T_0 = 0{\cdot}15$, $\xi_m = 1$ mm et $A = 1$ gal dans (5), on obtient $R = 175$ qui est réalisable avec une amplification mécanique ; car cet ordre d'amplification est toujours adopté dans un sismographe de haute sensibilité.

Après avoir discuté la grandeur de la masse, le moment d'inertie des leviers et le procédé d'amortissement, la construction de l'appareil a été exécutée dans l'atelier de notre Institut. Puis on a exécuté les étalonnages de l'appareil achevé et il a été installé dans une cave. On a, en effet, réussi à enregistrer un certain nombre de séismes apparus aux environs de Tôkyô. Nous allons alors rendre compte de la construction de cet appareil et des enregistrements obtenus avec.

2. Dimensions de l'appareil.

Il est certain qu'on est tout à fait libre quant au choix des dimensions de l'appareil. On a d'abord une masse oscillant sous l'action d'une force restitutive, dont la période n'est pas sensiblement modifiée par les moments d'inertie des leviers. Certes la grandeur de la masse dépend entièrement de la valeur du moment d'inertie du levier attaché et on peut donc réaliser un appareil comportant une masse relativement petite quand on adopte les leviers très légers.

On a pris un type de pendule représenté dans la Fig. 1, dont le cylindre (M) ayant 27·2 cm de longueur et 7·5 cm de diamètre, pèse 13 kg.

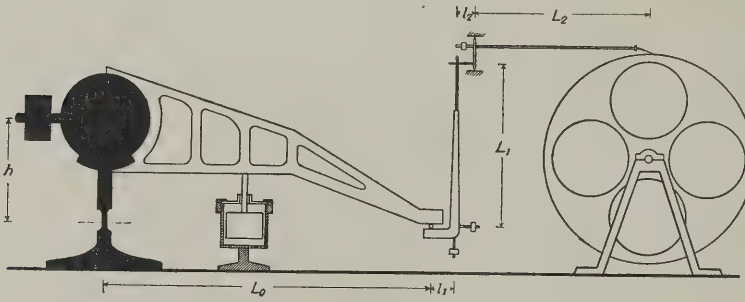

Fig. 1.

Il est tenu verticalement au moyen de deux lames d'acier fixées séparément le long de sa génératrice. En faisant tailler les deux lames, on peut amener la période de ce pendule à 0·15 seconde en la comparant par le procédé de Lissajous à un étalon vibratoire.

Il y a trois leviers qui servent à amplifier le déplacement de la masse : leurs dimensions sont :

leviers	bras inférieur	bras supérieur
1 er	h (9·2 cm)	L_0(28 cm)
2 me	l_1 (2 cm)	L_1(14 cm)
3 me	l_2 (1·5 cm)	L_2(15 cm)

Désignons par y le déplacement de la masse M, par ξ celui de l'extrémité du troisième levier et par θ_0, θ_1 et θ_2 les valeurs de la rotation de chacun des trois leviers, on a donc

$$\begin{aligned} y &= h\theta_0, & L_0\theta_0 &= l_1\theta_1, \\ L_1\theta_1 &= l_2\theta_2, & \xi &= L_2\theta_2. \end{aligned} \quad \cdots\cdots\cdots\cdots\cdots\cdots(6)$$

Par suite le rapport d'amplification géométrique totale devient ;

$$\frac{\xi}{y} = \frac{L_0L_1L_2}{hl_1l_2} = 213 \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(7)$$

Les valeurs du moment d'inertie des leviers sont déterminées d'une part par l'augmentation de la période du pendule quand on ajoute le premier levier ; d'autre part par le procédé d'oscillation d'un pendule tortionnel :

$$\begin{aligned} I_0 &= 71500 \text{ c. g. s.} \\ I_1 &= 212, \\ I_2 &= 9{\cdot}8. \end{aligned}$$

Naturellement tous les leviers sont disposés de manière que leurs centres de gravité soient sur les axes de rotation ; autrement les secouses pourraient influer directement sur la rotation des leviers.

3. Equations du mouvement.

L'expression générale de l'équation du mouvement d'un sismographe donné par l'équation (1) sera suffisante, sauf s'il n'y a pas de levier ou de frottement à l'extrémité de la plume. Dans le cas actuel, on est obligé de modifier plus ou moins l'équation (1). Le Prof. S. Ono[2] a déjà donné une série d'équations du mouvement qui sont applicables à des cas plus généraux. Mais comme il n'y a presque plus d'occasions d'utiliser un grand nombre de leviers, il est mieux de limiter les calculs à des conditions simples. On a les équations :

$$\left.\begin{aligned} I_0\ddot{\theta}_0 + 2\,k_0\dot{\theta}_0 + n^2_0\theta_0 &= -F_{01}L_0 - Mh\ddot{x}, \\ I_1\ddot{\theta}_1 \qquad\qquad &= \quad F_{01}l_1 - F_{12}L_1, \\ I_2\ddot{\theta}_2 \pm k_\xi L_2 \qquad &= \quad F_{12}l_2, \end{aligned}\right\}\cdots\cdots\cdots(8)$$

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[2] S. Ono, *Kisyô-syûsi*, [2], **5** (1927), 39.

où F_{01} et F_{12} sont les forces de réaction existant entre les deux leviers consécutifs, k_0 le coefficient dû à un amortisseur spécialement attaché au premier levier et k_ξ le coefficient du frottement mécanique à l'extrémité du troisième levier.

En éliminant F_{01} et F_{12}, et représentant θ_1, et θ_2 par θ_0, on obtient tout de suite l'équation suivante :

$$\left(I_0 + I_1\frac{L_0^2}{l_1^2} + I_2\frac{L_0^2L_1^2}{l_1^2l_2^2}\right)\ddot{\theta}_0 + 2\,k_0\dot{\theta}_0 + n_0^2\theta_0 \pm k_\xi\frac{L_0L_1L_2}{l_1l_2} = -Mh\ddot{x}.$$

Prenons le cas où k_ξ est négligiable ; on a

$$\ddot{\theta}_0 + 2\,\lambda\dot{\theta}_0 + n^2\theta_0 = -\frac{Mh}{I}\ddot{x}, \quad\cdots\cdots\cdots\cdots\cdots\cdots(9)$$

où $\quad I = I_0 + I_1\dfrac{L_0^2}{l_1^2} + I_2\dfrac{L_0^2L_1^2}{l_1^2l_2^2},\quad \lambda = \dfrac{k_0}{I}$ et $n^2 = \dfrac{n_0^2}{I}$.

En posant $x = a\sin pt$, on a la solution du mouvement forcé :

$$\theta_0 = \frac{Mh}{I}\frac{ap^2\sin(pt-\delta)}{\sqrt{(n^2-p^2)^2+4\,\lambda^2p}}, \quad\cdots\cdots\cdots\cdots\cdots(10)$$

où $$\delta = \tan^{-1}\frac{2\,\lambda p}{n^2-p^2},$$

dans le cas où $n >> p$,

$$\theta_{0m} = \frac{Mh}{n_0^2}a^2p = \frac{T_0^2}{4\,\pi^2h}ap^2, \cdots\cdots\cdots\cdots\cdots\cdots(11)$$

où T_0 est la période d'un système dont la masse M est concentrée en un point à la distance h de l'axe de rotation. Conséquemment la sensibilité d'un sismographe accélérométrique a toujours la même valeur, que l'on considère ou non le moment d'inertie des leviers qui amplifient le déplacement de la masse.

D'autre part, cependant, il est certain que la période propre de ce système augmente, si on ajoute des leviers comme le montre dans l'équation suivante :

$$\frac{T_0^2}{T_r^2} = \frac{Mh^2}{I} = \frac{Mh^2}{I_0 + I_1\dfrac{L_0^2}{l_1^2} + I_2\dfrac{L_0^2L_1^2}{l_1^2l_2^2}}.$$

On a donc besoin d'une assez grande masse dans un sismographe accélérométrique seulement pour que sa période propre ne varie pas sensiblement par l'adjonction d'un certain nombre de leviers. On peut, donc, réaliser un sismographe accélérométrique avec une petite masse à condition de chercher quelque moyen permettant l'enregistrant avec des leviers très légers.

Alors, on peut diviser I_0 en deux parties ;

$$I_0 = M\left(h^2 + \frac{r^2}{2}\right) + I_0',$$

où la première partie est le moment d'inertie du cylindre et la seconde partie est celui du premier levier ; on peut connaître la première d'après ses dimensions tandis qu'il faut faire une expérience pour connaître la valeur de la seconde. On a, enfin, pour les moments effectifs d'inertie des éléments :

$$\begin{array}{rl}
Mh^2 = & 1{\cdot}100 \times 10^6 \\
M\dfrac{r^2}{2} = & 0{\cdot}091 \quad \text{„} \\
I_0' = & 0{\cdot}072 \quad \text{„} \\
I_1\dfrac{L_0^2}{l_1^2} = & 0{\cdot}041 \quad \text{„} \\
I_2\dfrac{L_0^2 L_1^2}{l_1^2 l_2^2} = & 0{\cdot}167 \quad \text{„} \\
\hline
I = & 1{\cdot}471 \times 10^6
\end{array}$$

On a 0·15 s. pour la période d'un pendule comportant un cylindre tenu verticalement par deux lames d'acier et de suite la période réelle sera ;

$$T_r = 0{\cdot}15\sqrt{\frac{I}{M\left(h^2 + \dfrac{r^2}{2}\right)}} = 0{\cdot}167 \text{ seconde.}$$

Cette période sera convenable pour exécuter nos observations ; en tout cas le troisième levier donne une influence maxima faisant varier la période. On a adopté une tige de paille pour le troisième levier afin de diminuer le moment d'inertie le plus possible : mais il nous a semblé qu'il était presque impossible d'avoir une tige de 15 cm de longueur ayant un moment d'inertie inférieur à 8 c.g. s.

4. Amortisseur.

Pour amortir l'oscillation propre de ce système on met un amortisseur comportant un piston cylindrique plongeant dans une petite cuve remplie d'huile. Naturellement, le coefficient de viscosité varie énormément avec la température ; néanmoins on ne peut pas rejeter ce liquide à cause de cet inconvénient. Quand on adopte un amortisseur à air, on est obligé de réduire l'espace entre le piston et la paroi, et on ne peut empêcher que le contact entre l'un et l'autre ne se produise. Pour cette raison il est mieux d'utiliser une matière visqueuse. On fixe l'amortisseur à peu près au milieu du premier levier. La force d'amortissement γ rapportée à l'unité de vitesse est représentée par,

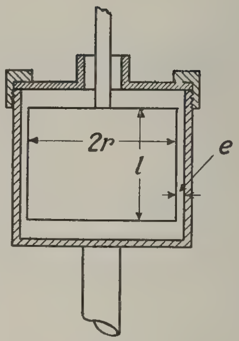

Fig. 2.

$$\gamma = \frac{6\pi l \eta r^3}{e^3}, \qquad \text{(13)}$$

où l est la longueur du cylindre, r son rayon, e l'espace entre le cylindre et la paroi et enfin η le coefficient de viscosité de liquide. La condition d'amortissement critique sera,

$$2\left(\alpha\frac{\gamma}{I}\right)^2 = \frac{4\pi^2}{T_r^2}, \qquad \text{(14)}$$

où α est le rapport entre la vitesse du piston et celle de la masse. En posant $r=2$ cm, $l=3$ cm, $e=1$ mm, $\alpha=1{\cdot}3$, $T=0{\cdot}16$ s et $I=1{\cdot}47\times10^6$, on peut estimer $\eta=1{\cdot}4$ c. g. s. près qui est une valeur habituelle pour la viscosité des huiles lourdes. En mélangeant du pétrole à l'huile à mécanisme, on obtient un liquide ayant la viscosité exigée. Après cette manipulation on a réussi à amortir le système, comme l'étalonnage exécuté nous l'a fait constater.

5. Frottement de la plume.

Comme l'extrémité du troisième levier glisse sur le papier recouvert de noir de fumée afin d'enregistrer les secousses, il faut considérer le frottement à la pointe ; cela joue un rôle important dans l'estimation du degré de précision des enregistrements obtenus.

La plume est en acier ou en tungstène, ce qui donne une pointe très fine, et un frottement aussi petit que possible. Certes, ce genre de frottement n'est autre que celui dû au contact de deux solides et il augmente à peu près propertionellement avec la pression de la pointe sur le papier, pression due au poids de la plume. Il est, en effet, préférable de la construire légère et cela nous a conduit à exécuter une expérience pour déterminer la valeur du frottement.

Une masse ayant un moment d'inertie (I) peut osciller comme le montre la Fig. 3. On attache à la masse un levier muni d'une plume dont la pointe est destinée à écrire l'oscillation sur le papier enroulé sur un tambour tournant. L'équation du mouvement est :

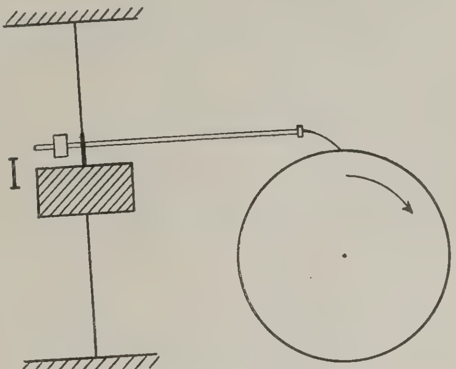

Fig. 3.

$$I\ddot{\theta} + n\theta \pm fL = 0, \quad \cdots\cdots\cdots\cdots(15)$$

où on prend + pour $\dot{\theta} > 0$, − pour $\dot{\theta} < 0$. La solution de cette équation sera

$$\theta = \left(\theta_0 \mp \frac{fL}{n}\right) \cos \sqrt{\frac{I}{n}}\, t \pm \frac{fL}{n}, \quad \cdots\cdots\cdots(16)$$

et

$$f = \frac{\pi^2 I}{2NT^2L^2}\,(2\,a_0 - 2\,a_N), \quad \cdots\cdots\cdots\cdots(17)$$

où N est le nombre d'oscillations, a_0 et a_N correspondent respectivement à la première et à la N^{me} amplitude. Avec une expérience on peut tout de suite déterminer la valeur de f; mais il y a en général un amortissement visqueux qui nous est indifférent pour notre but et on est obligé de considérer la valeur ultième de l'amplitude comme l'indique la Fig. 4. On prend l'amplitude d'oscillation pour l'abscisse et $2(a_n - a_{n+20})$ pour l'ordonnée. Dans la figure on trouve deux lignes droites dont l'inclinaison représente le degré d'amortissement visqueux qui est constante pour les deux lignes ; tandis que les valeurs ultièmes montrent ceux correspondant aux valeurs de frottement solide de deux plumes ayant des poids différents. Ces valeurs nous montrent que le frottement solide varie sensiblement avec le poids de la plume et enfin on a adopté une plume ayant le coefficient de frottement le plus petit. D'après cela, on a calculé la valeur de f: 0·19 dyne. Quoiqu'elle soit petite, il est necéssaire de considérer cette valeur qui est une cause de flexion des leviers.

L'action de ce frottement réagit sur la masse et la pointe n'enregistra

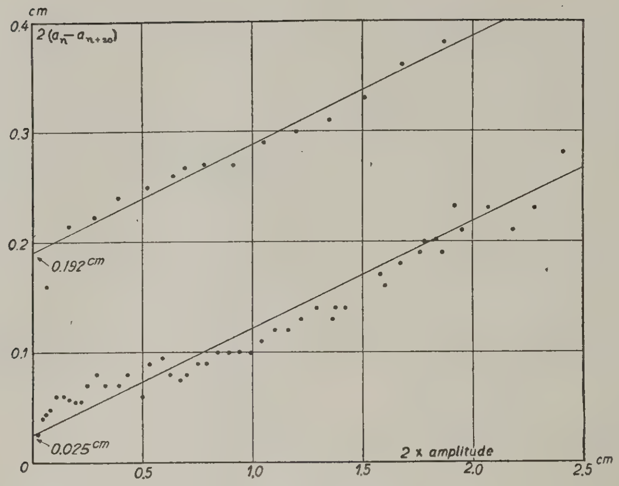

Fig. 4. $T=0{\cdot}714$ s. $I=3580$
$L=15$ cm $N=20$

plus d'accélérations inférieures à cette force. Cette accélération est $A = \frac{f}{M} \times 213 = 0{\cdot}0031$ gal qu'on peut considérer comme négligeable pour le but que nous poursuivons.

6. Flexion des leviers.

Il y a trois leviers dans notre sismographe accélérométrique qui servent amplifier le déplacement de la masse. Comme ils sont constitués par un corps élastique, il se produit des flexions sous l'action du frottement à l'extrémité du troisième levier ainsi que sous celle de rotation non-uniforme des leviers à cause de leur moment d'inertie.

Désignons par α la diminution du déplacement à l'extrémité du troisième levier, due à la flexion des leviers. On peut alors diviser α en trois parties correspondant aux trois leviers.

$$\left.\begin{aligned} \alpha &= \alpha_0 + \alpha_1 + \alpha_2, \\ \alpha_0 &= F_{01} D_0 \frac{L_1 L_2}{l_1 l_2}, \\ \alpha_1 &= F_{12} D_1 \frac{L_2}{l_2}, \\ \alpha_2 &= k_\xi D_2, \end{aligned}\right\} \quad \cdots\cdots\cdots\cdots\cdots\cdots(18)$$

où D_0, D_1 et D_2 sont les valeurs de la flexion détérminée expérimentalement sur chaque levier et rapportées à l'unité de force ;

$$D_0 = 2{\cdot}5 \times 10^{-9}$$
$$D_1 = 6{\cdot}9 \times 10^{-7}$$
$$D_2 = 1{\cdot}7 \times 10^{-4}$$

F_{01} et F_{12} sont les valeurs déterminées définitivement dans les équations (8). On a :

$$\left.\begin{aligned} F_{12} &= I_2 \frac{\ddot{\theta}_2}{l_2} + k_\xi \frac{L_2}{l_2}\,, \\ F_{01} &= I_1 \frac{\ddot{\theta}_1}{l_1} + I_2 \frac{\ddot{\theta}_2 L_1}{l_1 l_2} + k_\xi \frac{L_1 L_2}{l_1 l_2}\,. \end{aligned}\right\} \quad \cdots\cdots(19)$$

Quand le mouvement de la pointe sera représenté par l'oscillation sinusoïdale, on a

$$\ddot{\theta}_2 = \frac{4\,\pi^2 \xi_m}{L_2 T^2} \sin \frac{2\,\pi}{T}\, t.$$

Introduisons ces relations dans les équations (18), on obtiendra tout de suite,[3]

$$\begin{aligned} \alpha_{0m} &= \frac{\xi_m}{T^2}\, 26{\cdot}8 \times 10^{-6} + 2{\cdot}45 \times 10^{-6} \\ \alpha_{1m} &= \frac{\xi_m}{T^2}\, 11{\cdot}9 \times 10^{-5} + 1{\cdot}38 \times 10^{-5} \\ \alpha_{2m} &= \qquad\qquad\qquad\qquad + 3{\cdot}4 \times 10^{-5} \\ \hline \alpha_m &= \frac{\xi_m}{T^2}\, 14{\cdot}6 \times 10^{-5} + 5{\cdot}0 \times 10^{-5} \end{aligned}$$

D'autre part, on a $\alpha_m = \xi_m - \xi_m'$ où ξ_m' représente le déplacement maximum de l'extrémité de la plume en teuant compte la flexion des leviers ; on a donc

$$\frac{\xi_m'}{\xi_m} = 1 - \frac{a}{T^2} - \frac{b}{\xi_m}\,, \quad \cdots\cdots\cdots\cdots\cdots\cdots(20)$$

où $a = 14{\cdot}6 \times 10^{-5}$ et $b = 5{\cdot}0 \times 10^{-5}$. On représente cette relation dans la Fig. 5 montrant la dimunition de ξ_m rapportée à T. La diminusion de ξ_m ne dépasse pas de 4 pour cent, même dans le cas où $T = 0{\cdot}1$ s, $\xi_m = 0{\cdot}1$ mm.

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[3] nous avons pris k_ξ : 0·2 dyne.

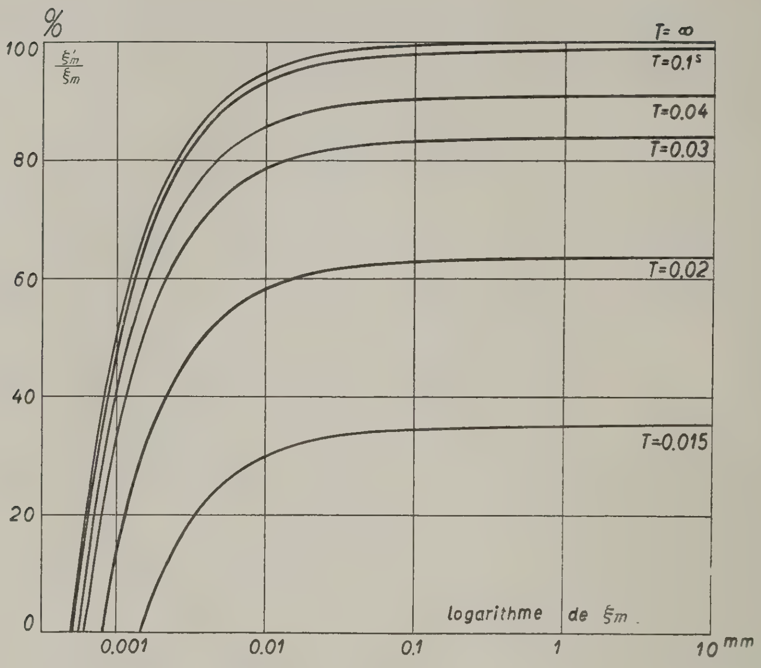

Fig. 5.

Tous les calculs sont faits jusqu'ici suivant l'hypothèse que les forces sinusoïdales agissent comme les forces statiques: ils sont appliquables, cependant, dans le cas où la période d'oscillation des leviers est très petite par rapport aux périodes des secousses sismiques. On a donc exécuté une expérience sur le troisième levier pour connaître sa période propre d'oscillation. Elle était $T = 1{\cdot}06 \times 10^{-2}$ s. qui est assez petite par rapport à celle des secousses sismiques.

7. Montage.

On a construit deux systèmes vibratoires identiques disposés de manière à enregistrer les deux composantes des secousses sur un seul tambour tournant. Le système pour la composante verticale est maintenant en construction et les détails seront publiés dans un prochain mémoire.

Les connections de deux leviers consécutifs sont faites avec beaucoup de précaution pour qu'il n'y a aucun jeu entre eux. Le premier est en contact avec le deuxième par l'intermédiaire d'une petite bille d'acier qui est maintenue pressée entre les deux au moyen d'un petit ressort. Le bras inférieur du troisième levier est constitué par un aimant qui fait un contact par pression avec le bras supérieur du deuxième levier.

Le tambour fait un tour complet en 10 minutes à l'aide d'un moteur synchrone[4] qui fait 300 révolutions par minute ; sa vitesse est, en effet, diminuée par deux étages de vis sans fin. On constate que la vitesse de rotation du tambour demeure assez constante pour qu'on puisse mesurer le temps très exactement sur les enregistrements obtenus. On a 5·65 cm de course par minute à la surface du tambour. La Fig. 6 est une photographie de cet appareil.

8. Etalonnages.

Pour verifier la sensibilité de cet appareil, on a exécuté une série d'étalonnages.[5]

La première expérience consiste à faire agir une force statique : soit une force de pesanteur, soit une force due à l'élongation d'un fil élastique de caoutchouc. Au crochet de la masse, on a attaché un fil de soie transmettant la force de pesanteur par l'intermédiaire d'une poulie ou simplement par la force d'un fil de caoutchouc dont l'élongation pour une force donnée est connue. Les résultats obtenus sont indiqués dans la Fig. 7 : ils nous prouvent que les déviations sont proportionelles à la force appliquée, et on peut donc calculer tout de suite la valeur de l'accélération représentée par les déviations de la plume.

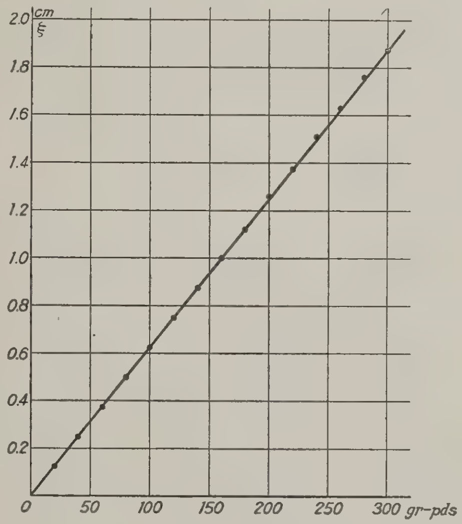

Fig. 7.

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4) F. Kishinouye, *Disin*, 2 (1930), 487.

5) Nous avons exécuté l'étalonnage sur No. 2 dont nous avons mis un petit ressort en contact des premier et deuxième leviers, cela nous a donné un peu de diminution de sa période ainsi que sa sensibilité.

On a alors 1 mm de déviation pour 1·20 gal d'accélération pour No. 2 A d'après la formule suivante:

$$\textit{Sensibilité}\ (\text{déviation de plume pour l'unité de l'accélération}) = \frac{mg}{M\xi}$$

La deuxième expérience est exécutée à l'aide d'un fil élastique de caoutchouc dont une extrémité est attachée au crochet, l'autre extrémité du fil étant animée d'un mouvement sinusoïdal d'amplitude constante et de différentes périodes; ce procédé d'expérience est déjà expliqué dans les mémoires précédents. Une courbe d'après les données est représentée dans la Fig. 8 où la courbe est toujours horizontale dans la

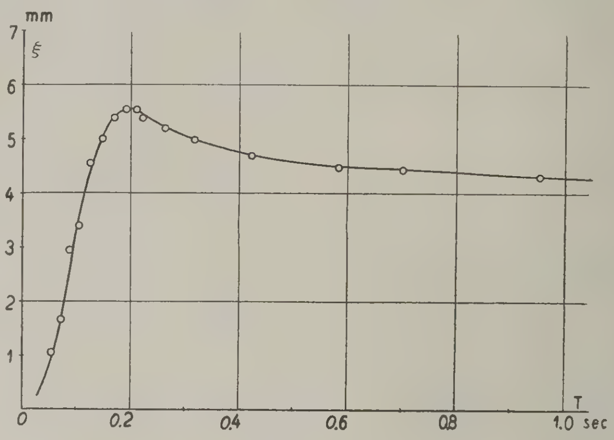

Fig. 8.

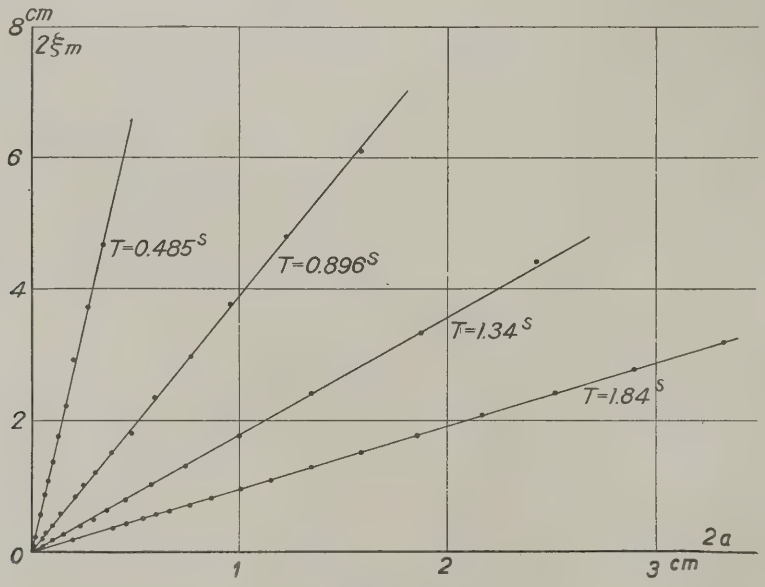

Fig. 9.

région considérée. On constate une diminution brusque de la sensibilité dans la région de période inférieure à 0·2 seconde. Cette caractéristique dépend simplement de ce que le système a une période propre d'une certaine valeur ; une telle relation a été déjà montrée théoritiquement dans un des mémoires précédents.

La troisième expérience a été faite sur une plate-forme oscillante suspendue par quatre montants de bois et le changement de sa période est réalisée en attachant un certain nombre de tiges donnant la force restitutive ; la force est à peu près proportionelle au nombre des tiges. Les résultats obtenus sont montrés dans la Fig. 9. De ces résultats nous pouvons tirer une certaine relation entre ξ_m et T. Pour 10 mm. de double amplitude de plate-forme on a :

$2\xi_m$	T	T^2	$2\,\xi_m T^2 (=4\,\pi^2\,2a)$
cm	s.		
0·93	1·84	3·39	3·22
1·79	1·34	1·80	3·21
3·96	0·896	0·803	3·13
13·6	0·483	0·233	3·20

où $\xi_m T^2$ est presque constante. Nous avons enfin la sensibilité de cet appareil comme $\xi = 1$ mm correspond à 1·23 gal.

9. Enregistrements obtenus.

En installant notre appareil[6] dans une cave de notre Institut pendant quatre mois, on a réussi à enregistrer un certain nombre de séismes dont malheureusement les intensités demeuraient comparativement petites. On a déjà parlé de la comparaison de l'accélération maxima déduite des enregistrements d'un sismographe de type ordinaire à celle obtenue directement par les enregistrement accélérométriques.[7] Constatant qu'il n'y a aucune coïncidence entre eux, on a proposé l'existence de deux sources d'erreurs ; il y a 1° la difficulté de connaître une onde ayant l'accélération maxima ; 2° l'inéxactitude de la rotation du tambour. On a, en effet, été obligé de comparer les ondes l'une après l'autre dans les deux sortes d'enregistrements.

Les trois enregistrements montrés dans les figures 10, 11, et 12 sont les secousses des séismes apparus dans la région de Kantô donnant des secousses perceptibles à Tôkyô. Leurs éléments sont

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[6] Cet appareil était le premier, et sa sensibilité n'st pas la même que celle du second surlequel on a montré les résultats d'étalonnage.

[7] *loc. cit.*

	Temps d'occurence (1931)					Epicentre8)	
Fig. 10	mars	25^j	15^h	30^m	$36{\cdot}8^s$	*E* 139°·1	*N* 36·°2
Fig. 11	..	27	5	25	35·9	*E* 140·4	*N* 35·3
Fig. 12	avril	4	9	16	41·9	*E* 139·3	*N* 35·5

Quand on compare les deux enregistrements de même composante, on s'aperçoit que toutes les petites ondes se correspondent l'une après l'autre. Naturellement, on ne peut pas distinguer les ondes dont la période est assez grande dans les enregistrements accélérométriques ; c'est parce que les accélérations des grandes ondes sont toujours petites.

D'autre part, dans les enregistrements obtenus par un sismographe de type ordinaire, les ondes de petite période disparaissent quand les ondes de grande amplitude et de grande période prédominent ; tandis qu'on trouve toujours les ondes de petite période dans les enregistrements accélérométriques. On accepte de ce fait deux sortes d'explications : l'une due au défaut mécanique d'enregistrement du sismographe, l'autre due au fait que les mouvements dus aux grandes ondes masquent les petites ondes. Il nous semble en tout cas que la vraie source du fait sera le dernier.9) On peut adopter un sismographe accélérométrique pour étudier surtout les petites ondes des séismes ; autrement dit, les études sur les séismes voisins seront mieux exécutées avec un sismographe accélérométrique : car on trouve que ce sont toujours les ondes de petite période qui y prédominent.

10. Remarques.

Nous avons l'intention d'exécuter des observations simultannées sur les séismes avec plusieurs stations munies des sismographes accélérométriques, afin de connaître les caractéristiques des secousses sismiques. On a déjà signalé des caractéristiques des secousses qui sont probablement des conséquences de l'hétérogéniété du milieu où les ondes sismiques

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8) déterminés par M. C. Yasuda.

9) Quand on regarde un sismographe pendant un séisme, on apprecoit souvant la plume qui oscille avec deux périodes de mouvements, mais il semble qu'elle écrit seulement les plus grandes ondes.

se propagent. Il est certain, donc, qu'on peut inversement imaginer que la croûte terrestre est composés de substances diverses ayant des paramètres d'élasticité différents.

Des enregistrements d'une seule station, on peut simplement classer les séismes en différents types rapportés à la direction de leurs hypocentres ; mais avec un certain nombre de stations, on peut avancer nos discussions sur les caractéristiques rapportées aux mêmes positions hypocentrales. En tout cas, quand on aura plusieurs enregistrements accélérométriques pour chaque séisme, on pourra aisément tirer quelques faits rapportés à la constitution de la croûte terrestre.

Pour discuter le phémomène de l'influence de l'accélération sismique sur la destruction des bâtiments, il nous faut attendre qu'un séisme assez fort nous permette des observations.

Pour terminer nous voulons exprimer nos vifs remercîments au Professeur K. Suyehiro, directeur de notre Institut, pour l'obligeance avec laquelle il nous a donné des suggestions de valeur et des discussions précieuses.

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22. 加速度地震計及び其の記象

地震研究所 石本巳四雄

1. 地震の加速度は其の周期より比較的短い周期を有する振動系の重錘の變位を目標として測定する事が出來るが、此の變位は極めて小である事から適當の方法を以て擴大する事が必要である。變位を器械的に擴大する事は困難であるが、地震動として考へられるものの中には 0·2 秒より小な周期を持つものが少ないと云ふ理由の下に振動系の周期も 0·15 秒附近であつて差支へない。今擴大率を 175 とすれば記象上 1 gal の加速度が 1^{mm} に相當する事となり、感度として適當なものとなる。而して此の程度の器械的擴大率は比較的高倍率地震計にも採用されて居る事から實現は可能となる。

2. 考案された加速度地震計の重錘は 13 kg の質量を有し、固有振動周期は約 0·15 秒に保たれて居る。重錘の變位は三つの桿杆によつて 213 倍に擴大される。桿杆の回轉能率は重錘に近きものから夫れ夫れ 71500, 212, 9·8 (c.g.s.) の値を有して居る。

3. 運動の式からすれば加速度地震計の感度は附加した桿杆の影響は無いが其の固有周期が大となつて目的に副はない事となる。即ち重錘の質量を大として周期の大とならぬ方法が講ぜられる一方、桿杆の回轉能率を極度に小にする事によつて質量を比較的小となす事が出來る。

4. 此の振動系の減衰は器械油を使用したピストン型の制動器によつて行はれて居る。油の粘度が溫度によつて多少は變化するが、此れは止むを得ない。

5. ペン先きが回轉圓壔上に振動を記錄するため、此所に固體摩擦がある。摩擦は實驗により測定され、小なるものの一例としては一回毎の振動に對して 0·38 dyne の力が働くと云ふ結果が得られた。

6. ペン先きの摩擦と桿杆に回轉能率とがある事から、振動を記錄する場合に桿杆に撓みが生ずる。此の結果周期の小なるものと振幅の小なるものとに對して影響が大である。此の減少率を實際の桿杆の有する諸量について計算したが、周期＝0·1 秒　變位 $\xi_m=0{\cdot}1^{mm}$ と云ふ場合でも 4% の減少である事が判明した。

7. 加速度地震計は二つの水平成分を別々に記錄する二つの振動系から成るが、記錄圓壔の回轉は小型同調電動機によつて行はれ、測時上極めて精度のよい結果を與へて居る。

8. 感度試驗は三種類のものが行はれた。第一は重錘に加へられた靜力によるものであるが、結局 1^{mm} の變位が 1·20 gal に相當して居る。第二の試驗はゴム糸によつて周期の異つた振幅の等しい力を重錘に與へて行はれ、其の結果は吾々の要求する範圍においては感度は一定である事が判つた。第三の試驗は振動臺上に器械を設置して行はれた。此の場合何れの周期に對しても殆ど同樣の感度が得られ、1^{mm} のペンの振れは 1·23 gal に相當して居る。

9. 器械は研究所地下室に設置して四ケ月間の觀測がなされたが、此の期間には比較的小さな地震の發生のみであつた。今村式50倍地震計と比較すると加速度記象は比較的小周期の波動のみを記錄するに反し、變位記象中には別に大周期の波が多分にする存事が判つた。後者においては大周期の波が小周期の波を隱蔽する傾向があるため、兩者の間に大なる隔絕を生ぜしめる如くであるが、其れは外觀上の問題と思はれる。大周期の波動に隱蔽されない部分においては明かに小周期の波動が一波毎に相當せしめる事が出來る事から見ても明かであらう。近地地震は多く小周期の波動を多分に有して居る事から、加速度地震計を以て記象せしめる方が有利である。記象が各震源方向に對して同一でない事は地震波の通過する地殼において彈性不均一の存在する結果と考へられる。

10. 加速度地震計を各地に設置する時は其等の記象から地殼の不均等狀況を推察し、又地殼構造に對して何等か研究が進められると期待される。家屋の破壞と加速度との問題に關しては適當な地震を待つ外はない。

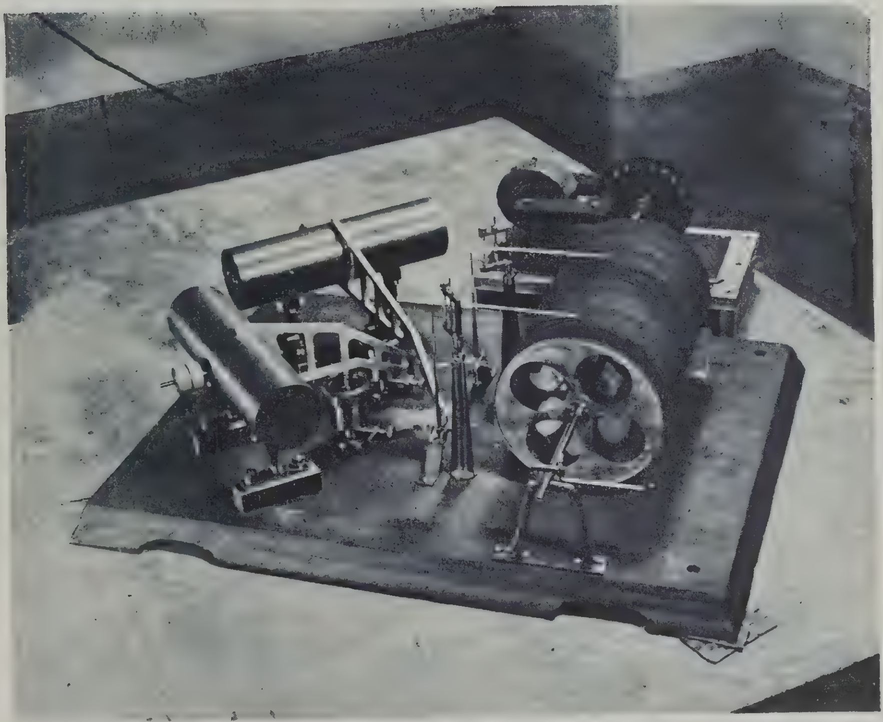

Fig. 6. Vue générale du Sismographe accélérométrique. Masse: 13 kg. Amplification géométrique: 213. Sensibilité 1 ^{mm} sur l'inscription= 1·23 gal. Période propre de l'oscillation: 0·15 s.

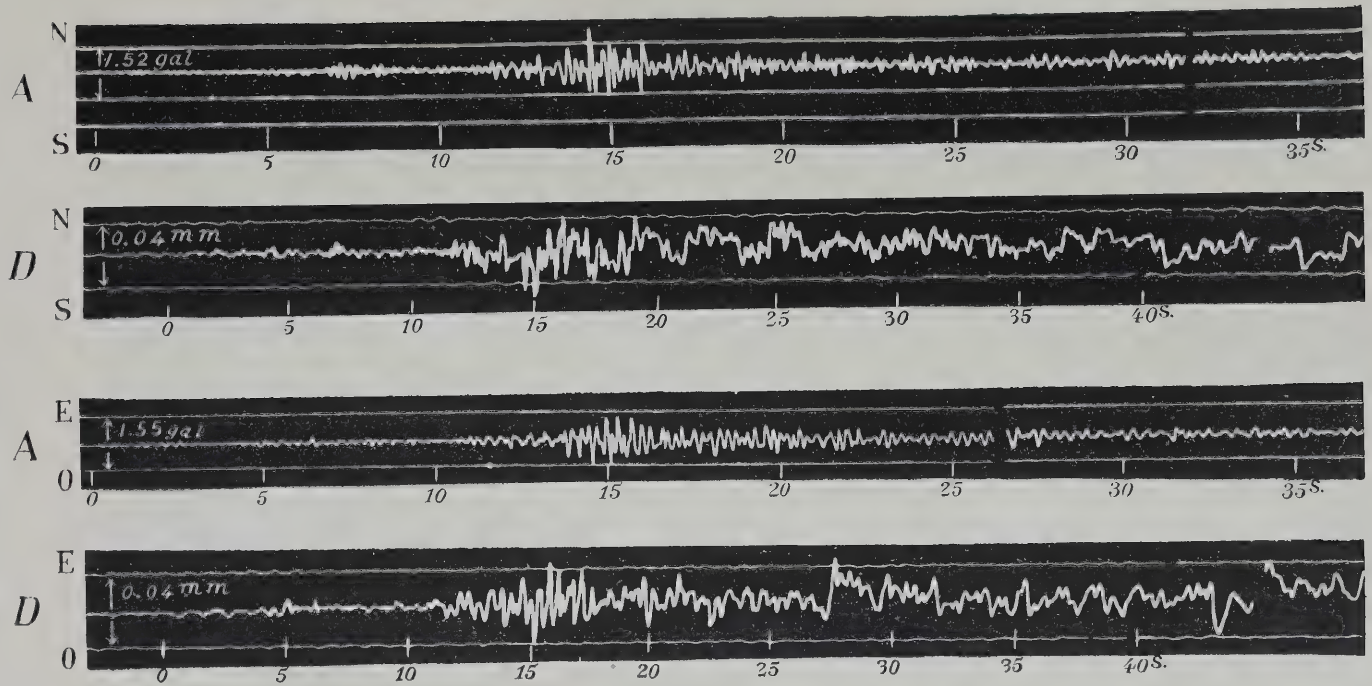

Fig. 10

Temps d'occurence: 26 mars 1931, $15^h30^m36{\cdot}8^s$ Epicentre: près de Maebasi E 139°·1 N 36°·2
A: Inscription accélérométrique; D: Inscription par le déplacement.

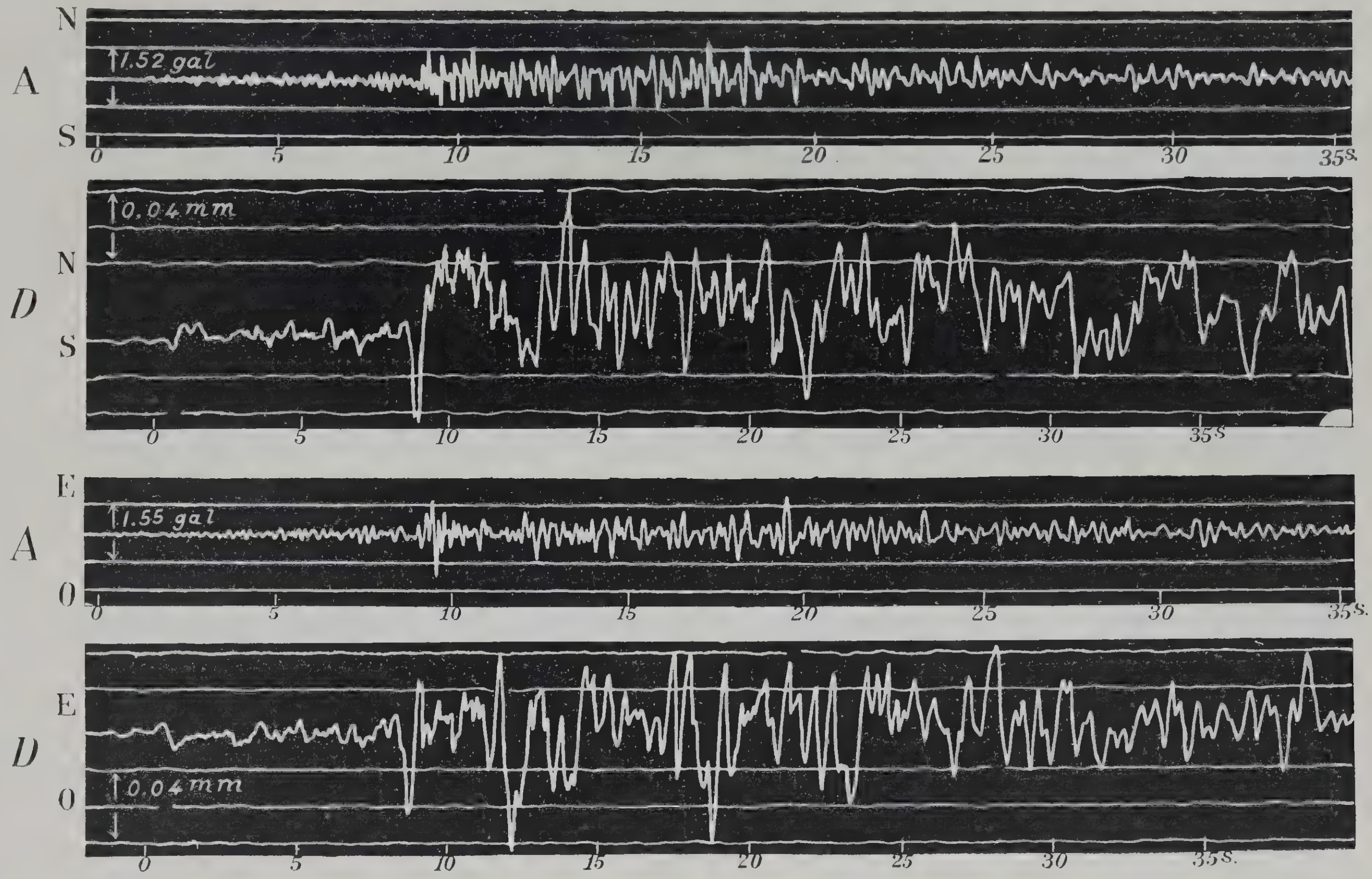

Fig. 11.

Temps d'occurence: 27 mars 1931, $15^h25^m35{\cdot}9^s$ Epicentre: près d'Itinomiya E 140·°4 N 35·°3

A: Inscription accélérométrique; D: Inscription par le déplacement.

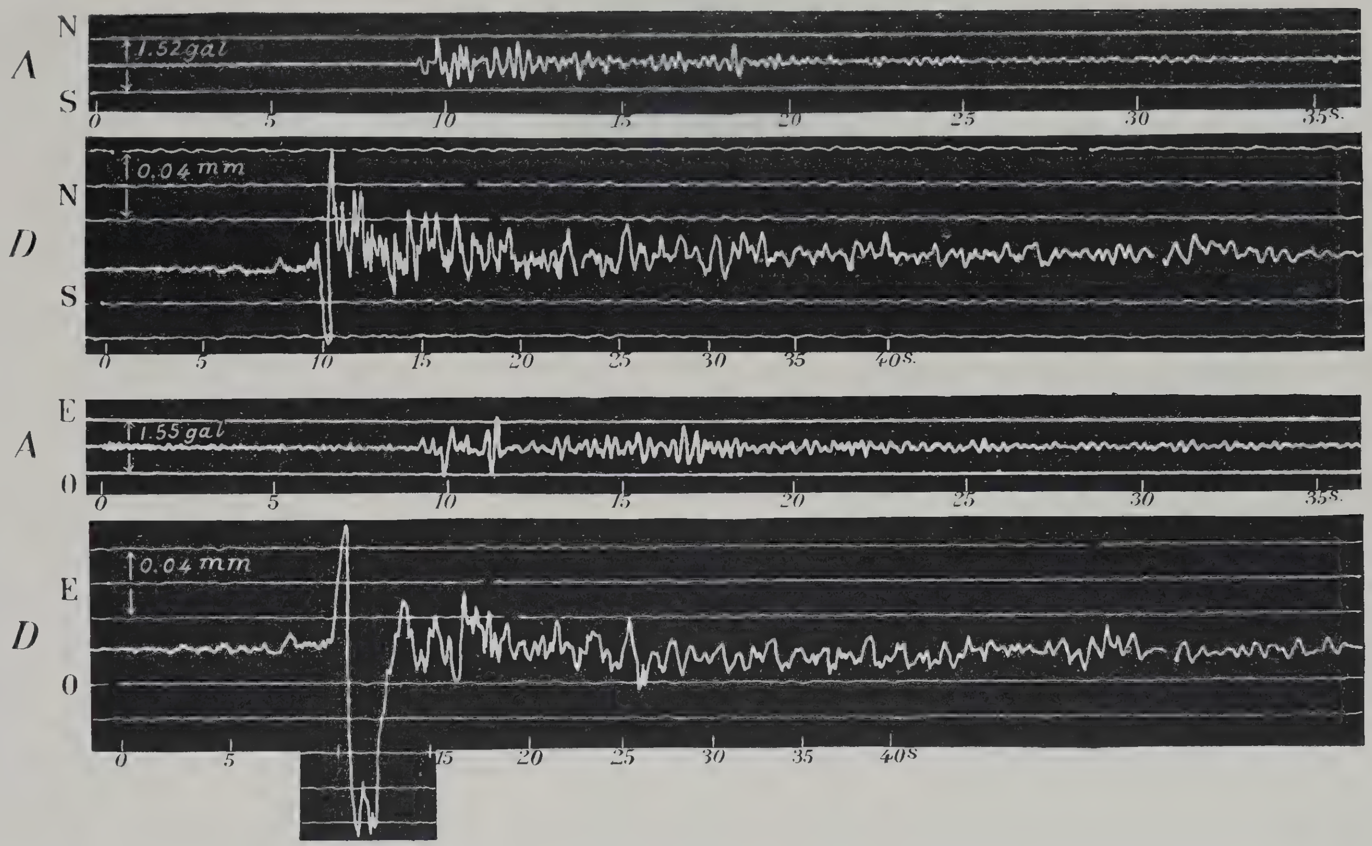

Fig. 12.

Temps d'occurence: 4 avril 1931, $6^h16^m41{\cdot}9^s$ Epicentre: près de Kawasaki E 139·°8 N 35·°5

A: Inscription accélérométrique; D: Inscription par le déplacement.

23. *Geological Growth of the Tôkyô Bay.*

By **Hisakatsu Yabe**,

Earthquake Research Institute.

(Read May 19, 1931.—Received May 17, 1931.)

The Tôkyô Bay is a rectangular depression in the Kwantô tectonic basin,[1] with an extension of 50 km. from north-east to south-west and 30 km. from north-west to south-east. Its four borders are more or less irregular; while the major irregularities are due to prograded deltaic deposits of the Sumida-gawa, Rokugô-gawa and several other rivers as well as to the sand spit of Futtsu, minor ones are the consequence of a land-submergence of 150± m., thereby the depression of the Tôkyô Bay and the ancient valley anteceding the Uraga Channel being invaded by transgressing marine water. This submergence of land was followed by an emergence of at most 20 m. The outline of the Tôkyô Bay with rectilinear borders suggests its tectonic origin; it is probably controlled by faults in two systems, one of NE-SW trend and the other of NW-SE. It may also deserve our attention that all the large swamps and lagoons (Tega-numa, Imba-numa, Kasumiga-ura and Kita-ura), dependent to the drainage system of the Tone-gawa, are situated on the north-eastern extension of this depressed zone.

The higher, Tama-, and the lower, Musashino-terraces[2] into which the plateau-surface of the Kwantô tectonic basin is divided are arranged in discordance with the area occupied by the Tôkyô Bay; this fact is a remarkable testimomy to the essential youth of the Tôkyô Bay, suggesting that its foundering dated later than the building of the two terraces, or in other words, later than the tectonic movements which led to the building of the Kwantô basin by basin-shaped uplift of the marine Narita Series; or more correctly, it may be considered as an episode of a later

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1) H. Yabe and R. Aoki, "The Great Kwantô Earthquake of September 1, 1923, Geologically Considered," *Ann. Rep. Saitô Gratitude Foundation*, No. 1 (1926).

2) R. Aoki and R. Tayama, "Topography and Geology of the Kwantô Tectonic Basin with Special Reference to Its Western Border," *Saitô Gratitude Foundation, Scientific Report*, No. 8 (1930), (in Japanese).

date intervening this long continued tectonic movement which gave rise to the Tama- and Musashino terraces. Perhaps it was also anteceded by the deposition of the Kwantô loam upon the surface of the two terraces.

Hence the Tôkyô Bay is not a relic sea of the older, Palaeo-Tôkyô Bay,[3] in which the marine sediments of the Narita Series are thought to have been deposited.

The Tôkyô Bay is shallow, not exceeding 60 m. in depth; the basin was in terrestrial condition before the land submergence referred to above, as indicated by the drowned valley in the Uraga Channel.[4]

The Uraga Channel is zigzag-shaped, parallel-sided and 10 km. broad on the average; its floor gently descends from 60 m. at the north to 80 m. at the south, and has a drowned valley running lengthwise on its floor. There is no trace of the Tama- and Musashino-terraces fringing the periphery of the channel, and it has in common with the outer sea and the Tôkyô Bay only the coastal topography of the last land-submergence and raised-beaches telling younger, the last emergence.

The silt beneath the soil of the Downtown of Tôkyô is an estuarine deposit of the time of the last land-submergence, later uplifted; it occasionally contains numerous mollusca characteristic of a muddy bottom, as that once excavated at Yûraku-chô, Kôjimachi-ku[5]; it is a kind of bay-head deposits in drowned valleys, and contemporaneous deposits of similar nature occur also along the both sides of the Uraga Channel, for instance, at Uraga on the west side and Minato on the east. The molluscan fauna of these raised beaches does not essentially differ in its constitution from the recent one living in the Tôkyô Bay under the same physical condition.

The contemporaneous raised beaches exist not only along the Sagami Bay coast of Sagami and the Miura Peninsula, and around the Bôsô Peninsula outside the Uraga Channel, but also almost everywhere around the Japanese Islands where they were not destroyed by later abrasion, either marine or subaerial; there are primarily absent only where a local crustal disturbance caused the shifting of the strand line more in opposite sense, as, for instance, in the southernmost part of the Kitakami Mountainland and in the Matsushima-Shiogama district.[6]

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[3] In Ôiso block, Miura and Bôsô Peninsulas, the grouping of the strata shows that we are dealing with the surviving remnants of the late Neogene range that ran along the northern border of the present Sagami-nada and crossed the Uraga Channel; this horst mountain struck farther south-south-eastward into the Pacific. The crust-block sunken north of it converted into a bay, open to east and south-east; for this Pleistocene bay, the name Palaeo-Tôkyô Bay was proposed by me many years ago. H. YABE, "Bôsô Peninsula" *Gendai no Kwagaku*, 2 (1914), No. 4, (in Japanese).

[4] H. YABE and R. TAYAMA, "On Some Remarkable Examples of Drowned Valleys found around the Japanese Islands," *Records Oceanogr. Wks.*, Japan, 2 (1929), No. 1.

[5] G. YAMAKAWA, "Alluvial Mollusca from Yûraku-chô," *Jour. Geol. Soc.*, Tôkyô (1909), (in Japanese).

The raised beaches constitute one particular group of terraces which are geologically the youngest ones among the so-called "Post-Kwantô loam terraces" of Messrs. R. AOKI, and R. TAYAMA,[7] and may hereafter be called "the 15 m. beaches" for the sake of brevity, though their altitude much differs from place to place and ranges usually from less than 5 m. to 20 m. in the Kwantô region.

One of the "15 m. beaches", which is the most instructive of all, is the coral bed, or more correctly coral reef, of Noma near Tateyama and along the Tateyama-wan, in the province of Awa, where an alluvial plain has its surface some 20 m. higher than the present sea-level. As shown by many excavations at Okanoma and several other places near by, there is in a more or less extended distribution an incipient fringing reef of reef-building corals beneath the alluvial silt, which had once grown in drowned valleys, cut into Neogene rocks, at the time of the last land submergence, referred to above.

The semifossil reef is about 2–3 m. thick and consists of coral heads or stocks in upright position, the basal ones of which attach directly to the rock-floor, Neogene tuffs of the Miura Series, or to angular or subangular blocks of the same rocks torn off from the very floor and rolled.

Other common organic remains in association with these corals are thick-shelled mollusca, all found in fresh condition, not seldom with colour pattern and bivalves having both valves usually intact. The corals are likewise well preserved, even delicate spinules of septal margin usually showing no trace of damage. Worthy of special note is further the circumstance that there are almost no rolled pieces of coral stocks around the reef; at least these were not seen in an excavation of Okanoma which I had an opportunity personally to examine a score of years ago, and in another one very recently prosecuted by members of the Institute

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6) H. YABE, "Excursion to Matsushima and Sendai; Geological Guide," Guide-Book, Excursion C 3, published by the Pan-Pacific Science Congress, 1926.

7) R. AOKI and R. TAYAMA, *op. cit.* R. TAYAMA, "Topography of the Bôsô Peninsula, with Special Reference to the Correlation of Abrasion Planes," *Saitô Gratitude Foundation, Scientific Reports*, No. 9 (1930), (in Japanese).

of Geology and Palaeontology, Tôhoku Imperial University. All these facts seem to support the view that we have here an incipient fringing reef grown in a rather calm water immediately after the land submergence.

There is a divergence of opinions as to the geological age of the Noma coral reef. Dr. M. YOKOYAMA at first maintained the Pleistocene warm age instead of glacial in Japan on the evidence of this formation; but later assigned it to the youngest Pleistocene.[8] In my opinion it is early Holocene as already expressed elsewhere.[9] Mr. T. KURODA of the Institute of Geology and Mineralogy, Kyôto Imperial University, verbally communicated me that the molluscan fauna of the semifossil reef of Noma is similar to the recent one living in the adjacent warm water. The question of the geological age of the coral reef is intimately related to the larger problem how to mark the Pleistocene-Holocene boundary in the Japanese Islands, where we have no trace of past glaciation else than scanty small cirques on the high peaks of the Hida-Shinano Mountains or the so-called Japanese Alps[10] and the Hidaka Mountains of Hokkaidô. The topographical relation of these cirques to the valley-terraces in the mountains and that of the latter to the Tama and Musashino terraces have not yet been thoroughly studied by any of us, though these are topics of our keen interest.

In this connection, very interesting is a comparison between the British Islands (especially of non-glaciated areas) and the Japanese Islands as to the change of sea-level and climate during the latest Cenozoic. Our 15 m. beaches and terraces may approximately correspond to the so-called Neolithic beaches of the British Islands and the stage of land-submergence preceding to the emergence has its exact copy in the land-submergence by which the stage of the Neolithic beaches is separated from the so-called Forest stage, while the Forest stage seems to found its counterpart in the time during which our Tama and Musashino terraces were formed. Then the best way from the stand-point of diastrophism is, I think, to mark the dawn of the Holocene with the last land-submergence in the Japanese Islands, as already definitely stated by me several years ago.[11] So far as I am now aware, all the neolithic human sites and shell mounds in the Kwantô region with dressed and polished stone implements as well as potteries are situated on the 15 m. beaches and terraces or on the Kwantô loam covering the Tama- and Musashino-terraces.

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[8] M. YOKOYAMA, "Climatic Changes in Japan since the Pliocene Epoch," *Jour. Coll. Sci. Imp. Univ.*, Tôkyô, **32** 1911), Art. 5 M YOKOYAMA, "Mollusca from the Coral-Bed of Awa," *ibid.*, **45** (1924), Art. 1.

[9] H. YABE and R. AOKI, "A Summary of the Stratigraphical and Palaeontological Studies of the Cenozoic of Japan, 1920 to 1923," *Proc. Pan-Pacific Sci. Congr.*, Australia (1923).

[10] N. YAMASAKI, "Glaciation of the Hida Mountains," *Geol. Soc.*, Tôkyô, **21** (1914), (in Japanese). K. ÔSEKI, "Some Notes on Glacial Phenomena in the North Japanese Alps," *Scot. Geogr. Mag.*, **31** (1915).

Finally it remains to settle the relative antiquity of the depression of the Tôkyô Bay and the building of the older terraces of the " Post-Kwantô loam terraces ", because the latter, like the former, is a geological event preceding the last land-submergence. An answer to this question can be obtained by a glance of the terrace map of the northern part of the Bôsô Peninsula by Mr. R. TAYAMA,[12] which distinctly shows that the older terraces of the " Post-Kwantô loam terraces " are nearly conformant in their areal distribution with the present drainage system of the district, fringing even small, apparently young side-valleys. Hence there is almost no doubt about that the older terraces of the " Post-Kwantô loam terraces ", like the younger ones, are of the later origin than the depression of the Tôkyô Bay, at least in this district now we specially concern, though of course it is never the truth to say that every one of the terraces of this category has the same history, because we have good reason to believe that the emergence of land was continuously in progress in the Kwantô basin as before as after the foundering of the Tôkyô Bay, and the possibility is by no means excluded that some of the terraces are decidedly of an earlier date.

Summary.

From the foregoing remarks it appears reasonable to subdivide the Shikishima Period (the Japanese Pleistocene + Holocene)[13] by the use of various diastrophic criteria in the following way, in so far as the Kwantô region is concerned.

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[11] H. YABE and R. AOKI, " A Summary of the Stratigraphical and Palaeontological Studies," *lcc. cit.*

[12] R. TAYAMA, " Topography of the Bôsô Peninsula," *loc. cit.*

[13] H. YABE and R. AOKI, " A Summary of the Stratigraphical and Palaeontological Studies," *loc. cit.*

1. Land submergence in the early Shikishima Period and the deposition of the marine Narita Series in the Palaeo-Tôkyô Bay on the submerged land surface called by YABE the Pre-Narita and believed to be equivalent to the Pre-Tama of Messrs. AOKI and TAYAMA.[14]
2. Land emergence, elevating the Narita Series above the sea level; subaerial denudation and the building of the Tama terraces.
3. Crustal disturbance as indicated by the different behaviours of the Tama and Musashino terraces.
4. Land emergence and subaerial denudation continued; building of the Musashino terraces.
5. Deposition of the Kwantô loam upon the surface of the Tama and Musashino terraces.
6. Land emergence and subaerial denudation continued; depression of the Tôkyô Bay and building of the older ones of the "Post-Kwantô loam terraces".
7. The last land submergence; giving rise to the drowned valleys of the higher level[15]; the deposition of the sediments of the 15 m. beaches and terraces; growth of the Noma fringing reef. Early Holocene.
8. The last land-emergence; building of 15 m. beaches and the other terraces of the younger group of the "Post-Kwantô loam terraces".

23. 東京灣の出現

地震研究所 矢部長克

今日の東京灣の占むる地域は、共の輪廓より窺ふに、北西ー東南及び北東ー西南の二組の地質構造線の間に挾さまれたる沈下地塊の如し。然して此の沈下は青木及田山兩氏の多摩及び武藏野臺地の形成後にして且つ後關東ローム段丘の內、新期のものに先んず。此れ東京灣盆地の出現の時期にして此の盆地が海水の浸す所となりたることは上述最後の段丘の一種たる十五米隆起汀線海成堆積層の示す陸地沈降即ち海浸の時期なり。

此の日本群島最近地史の上に著るしき陸地沈降及び上昇は英群島の所謂ネオリシツク、ビーチの示す水準變化と全く共の軌を一にして又同時代のものなるべし。

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[14] R. AOKI and R. TAYAMA, "Geology and Topography of the Kwantô Tectonic Basin," *loc. cit.*

[15] H. YABE and R. TAYAMA, "On Some Remarkable Examples of Drowned Valleys," *loc. cit.*

成田層堆積當時に於ては、箱根の北より大磯地塊、三浦及び房總兩半島を連ぬる東西趨向の山地又は丘陵地ありて、其の北に成田層の沈積を見たる一大海灣あり。東及東南太平洋に開く。然して上記の事實より現在の東京灣は此の所謂古東京灣とは全く別個の成生に係り前者は後者の遺跡ならざるを知る。

24. *Early Pliocene Crustal Movement in the Outer Zone of Southwest Japan and in the Naumann's Fossa Magna.*

By **Yanosuke ÔTUKA,**

Earthquake Research Institute.

(Read June 16, 1931.—Received June 20, 1931.)

The object of this communication is to describe an interesting structural feature of the lower Pliocene strata in the Outer Zone of Southwest Japan[1] and in the Naumann's Fossa Magna.[2]

The areas dealt with are plotted on the accompanying index map (Fig. 1); these are:—

1. The northeastern part of Miyazaki prefecture, along the southeastern coast of Kyûsyû.
2. The eastern part of Kôti prefecture along the Tosa bay.
3. The Kakegawa district, west of Siduoka.
4. The Asigara district, adjoining to the north of the volcano Hakone.
5. The Nagano prefecture.

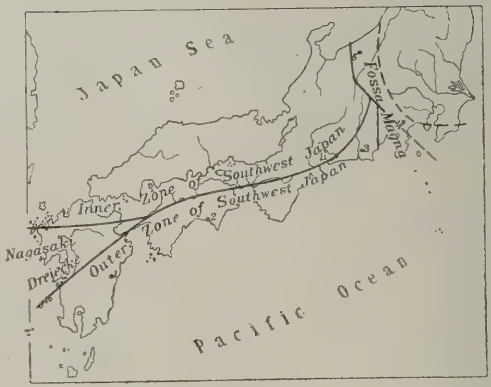

Fig. 1.

The first three districts of the above list are sited in the Outer Zone of Southwest Japan and the latter two are in the Fossa Magna.

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[1] Dr. H. Yabe divided the southwest Japan into two parts, the inner or northern side and the outer or southern side, with his median dislocation line, which is the boundary line between the Izumi sandstone and gneiss on one side and the crystalline schists and the lower Chichibu series on the other.

[2] The term "Fossa Magna" was proposed originally by E. Naumann to the transverse divisional zone between the southwest Japan and the northeast Japan. Western border of the Fossa Magna is the Itoigawa-Siduoka line of Dr. H. Yabe.

1. The northeastern part of Miyazaki prefecture, along the southeastern coast of Kyûsyû.

The northeastern part of Miyazaki prefecture is built up of Mesozoic deposits, of which the precise geological age is still unknown, porphyrite, older and younger Tertiary and Quaternary in ascending order.

Dr. T. Iki[3] who first studied the geology of this district gave some accounts of the younger Tertiary in his explanatory text to the geological map of Japan, 1 : 200.000, the Sadowara sheet, 1896, published from the Imperial Geological Survey. Later Dr. H. Yabe[4] made a reference to an *Operculina*-rocks in Japan, and Dr. M. Yokoyama[5] published in 1928 the result of his thorough study of fossils collected by Mr. T. Kobayashi from the formation, thereby describing 119 species. The following accounts of the younger Tertiary formation of this district is an outcome of my field work carried on late in the spring of 1930.[6]

The area occupied by Neogene strata is a dissected raised coastal plain, called the Hyûga coastal plain, drained by the rivers Omaru and Hitotuse ; it is trianguler in outline, bounded by the Hyûga-nada (Hyûga sea) coast on the east and Osuzu mountainland and Higasimorogata mountainland on the other two sides.

The general sequence of the younger Tertiary deposits as observed between the Omaru and Hitotuse is as follows, in descending order :

$$\text{Takanabe group}\left\{\begin{array}{l}\text{Heki beds}\\ \text{Kôonzi beds}\\ \text{Sadowara beds}\end{array}\right.$$

Tuma group

The Takanabe group which occupies the eastern portion of the area (Fig. 2) is divisible into Heki beds, Kôonzi beds and Sadowara beds. The upper member, Heki beds, is essentially gray sandy mud, intercalating two pumiceous zones and sometimes enclosing calcareous nodules : there are many fossiliferous zones in this complex. The Kôonzi beds consist of mud and silt in thin-bedded alternation and have fossiliferous zones. The Sadowara beds consist of barren sand and mud in the northern part of the area, which gradually pass into brown fine grained conglomerates in the southern part of the area; an archætypal *Stegodon* reported by Dr. Yokoyama[7] is from the latter.

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[3] T. Iki, *Expl. Text Geol. Map Japan,* " Sadowara " Sheet, 1: 200.000, (1904).

[4] H. Yabe, " Notes on *Operculina*-Rocks from Japan, with Remarks on *Nummulites cumingi* Carpenter ", *Sci. Rep. Tôhoku Imp. Univ.,* II ser., **5**, 1 (1918).

[5] M. Yokoyama, " Pliocene Shells from Hyûga ", *Jour. Fac. Sci. Imp. Univ.,* Tôkyô, Sect. II, **2** (1928), 331–350.

[6] Y. Ôtuka, " Some Geologic Problems in the Southwestern Coast of Kyûsyû ", *Georg. Rev.,* Japan, **6**, 7 (1930), (in Japanese).

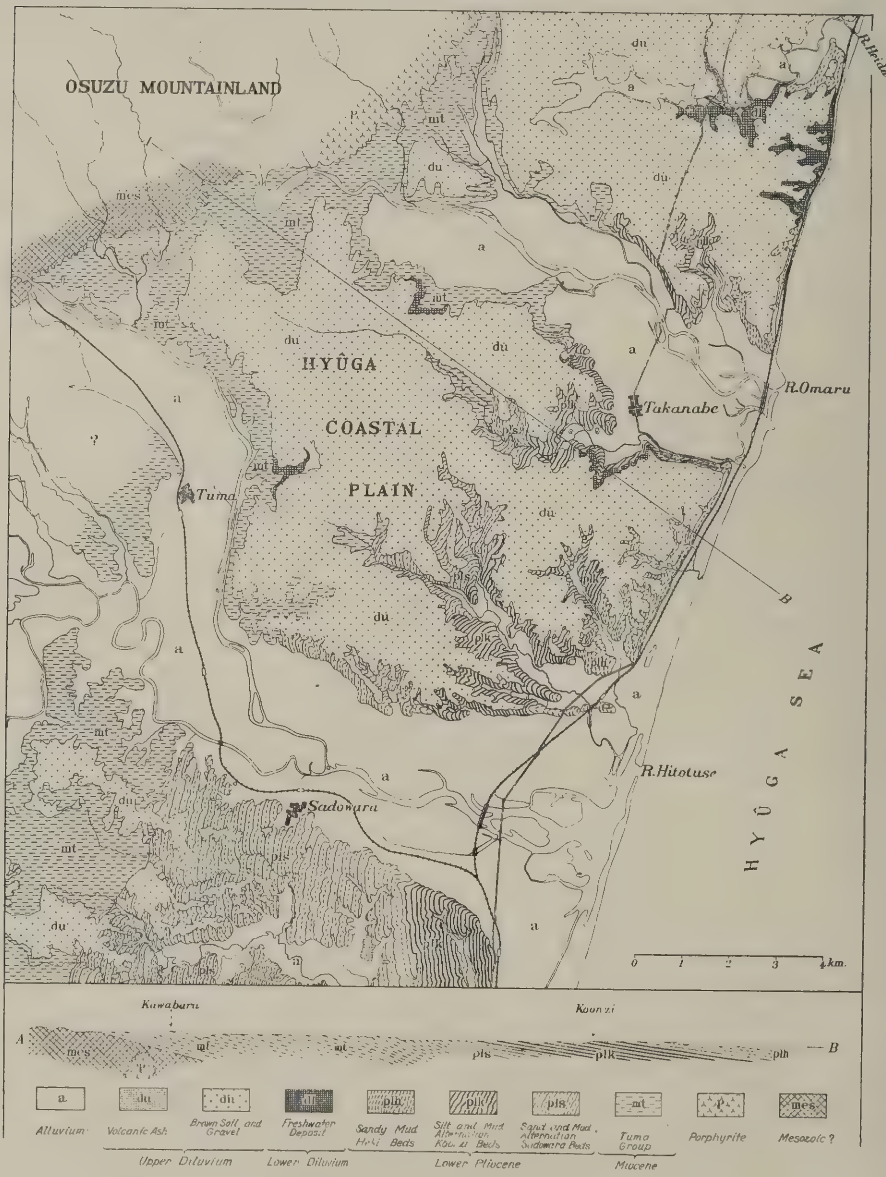

Fig. 2. Geological Map of Hyûga Coast by Yanosuke Ôtuka.

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[7] M. Yokoyama, "*Stegodon* from Uryûno, Miyazaki Prefecture", *Jour. Geol. Soc.*, Tôkyô, 20 (1913), 236, (in Japanese).

Of numerous species of the fossil shells found in the Takanabe group, *Anadara satowi castellata* (Yokoyama), *Glycymeris nakamurai* Makiyama, *Pecten* (*Amussiopecten*) *praesignis* Yokoyama, *Venericardia panda* (Yokoyama), *Umbonium suchiense* Yokoyama, *Umbonium suchiense subsuchiense* Makiyama, *Umbonium mysticum* Yokoyama, *Clavatula dainichiensis* Yokoyama, *Latrunculus eratus* (Yokoyama) etc., are specially worthy of note, because of their being also common and characteristic species of the lower part of the Kakegawa series of Dr. J. Makiyama,[8] to be mentioned later on.

The older, Tuma Group, which occupies the western part, consists of unstratified thick dark gray muds in its upper part and stratified sands in the lower. It covers the older basement complex in clinounconformity with its base on the west almost coinciding with the topographic boundary between Osuzu mountainland and the Hyûga coastal plain.

The structural arrangements of these younger Tertiary complexes are regular, having the strike varying from N 20° E to N-S and hence generally parallel to the shoreline of the plain and the dip about 10° NE or E: the general strike and dip, however, are sometimes affected by local foldings or other disturbances. Freshwater deposits, presumably of the lower Pleistocene age, rest horizontally upon these groups in a few isolated patches. Fig. 2 is a map showing the geologic structure of this district and a profile on the line AB, which is normal to the general trend of the younger Tertiary.

2. The eastern part of Kôti prefecture along the Tosa bay.

The first geological survey of this district was prosecuted by Dr. T. Ogawa[9] and the late Y. Ôtsuki,[10] the author of the explanatory text to the geological map of Japan, 1 : 200.000, the Kôchi (Kôti) and Muroto sheet respectively, which contain many instructive geological accounts worthy of special attention.

In the explanatory texts to the geological map of Japan, 1 : 75.000, the Muroto[11] and Kôchi[12] (Kôti) sheet, Mr. T. Suzuki ascribed middle Pliocene age[13] to the upper Tertiary deposits of this field which rest unconformably upon the formation of Mesozoic ? rocks and consist of marine conglomerate and sand. Prior to this, Dr. J. Makiyama[14] found *Umbonium mysticum* Yokoyama, a characteristic fossil of his lower part of the lower Kakegawa series, and suggested the contemporaneity of one part of the fossiliferous deposits and the lower part of the lower Kakegawa series. According to Mr. T. Suzuki, the middle Pliocene beds occupy small isolated patches along the coast of Aki-gun, Kôti prefecure, with a slight seaward dip; the strike turns from NE in the southern part to N 60° W or even to E-W in the northwestern. The younger Tertiary deposits are covered by horizontal gravel beds presumably of the Pleistocene age. Fig. 3 is a geological map, after T. Suzuki, showing the distribution of the Pliocene and Pleistocene deposits in this area.

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[8] J. Makiyama, "Molluscan Fauna of the Lower Part of the Kakegawa Series in the Province of Tôtômi, Japan", *Mem. Coll. Sci. Kyôto Imp. Univ.*, Ser. B. 3, 1 (1927).

[9] T. Ogawa, *Expl. Text Geol. Map Japan*, "Kôchi" sheet, 1:200.000, (1905).

[10] Y. Ôtsuki, *Expl. Text Geol. Map Japan*, "Muroto" sheet, 1:200.000, (1902).

[11] T. Suzuki, *Expl. Text Geol. Map Japan*, "Muroto" sheet, 1:75.000, (1930).

[12] T. Suzuki, *Expl. Text Geol. Map Japan*, "Kôchi" sheet, 1:75.000, (1931).

[13] M. Yokoyama, "Pliocene Shells from Tônohama, Tosa", *Imp. Geol. Surv.*, Japan, Rep. 104 (1929).

3. The Kakegawa district, west of Siduoka.

It was in the explanatory text to the geological map of Japan, 1: 200.000, Shidzuoka (Siduoka) sheet (1886), that the late Dr. K. Nakajima[15] divided the Tertiary deposits of the area covered by the sheet into the upper and the lower Ôigawa. For a long time since, stratigraphical details and faunal nature of the Tertiaries had been studied by nobody. First several years ago, Mr. Y. Chitani[16] and Dr. J. Makiyama[17] independently begun their researches on the Tertiaries in the Kakegawa district, west of Siduoka, and the recent rapid progress of our

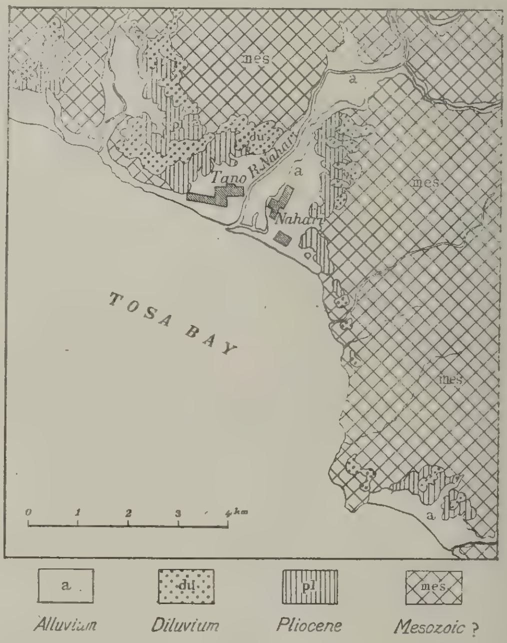

Fig. 3 Geological Map of the Eastern Part of Kôti Prefecture along the Tosa Bay. (After T. Suzuki).

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[14] J Makiyama, *op. cit.*, (1927), 21.

[15] K. Nakajima, *Expl Text Geol. Map Japan*, "Shidzuoka" sheet, 1:200.000, (1886)

[16] Y Chitani, "The Tertiary in the Vicinity of Kakegawa and Sagara, Tôtômi", *Journ. Geogr.*, 38 (1926), 84–89, (in Japanese).

[17] J. Makiyama, "On the Geology near Kakegawa, Shidzuoka Prefecture", *Chikyû*, 9, 1–2 (1928), (in Japanese).

knowledge on the subjects is essentially due to the works of the two authors.

According to Dr. J. Makiyama,[18] the Mesozoic and Cainozoic formations developed in the eastern part of Tôtômi are divisible into eight groups of Mikura (Cretaceous or Palaeogene), Ôigawa (lower Miocene or older), Sagara (upper Miocene), Horinouchi (Horinouti) (transition), Kakegawa (lower Pliocene), Soga (upper Pliocene), Ogasa conglomerate (upper Pliocene), and Pleistocene gravel deposits.

The Kakegawa series is a formation about 640 m. thick in its type locality treated by Dr. Makiyama, where it represents a complete cycle of sedimentation. Its stratigraphical relation to the underlying Soga is marked unconformity. The averaged dips of these strata are 10°–15° and the strike is usually about N 50° W. There are small dip- and strike-faults, and also very slight folding of strata.

The area covered by the geological map of Japan in 1 : 75.000, Sagara sheet (1927) by Mr. Y. Chitani[19] includes the southern part of Makiyama's field, and in the southern part of this sheet, the younger Tertiary strata have the dips 10°–30° SW and the strikes ranging from N 10° W to N–S. EF in Fig. 5 is a geologic profile, after Y. Chitani, at right angles to the main strikes of the younger Tertiary.

4. The Asigara district adjoining to the north of volcano Hakone.

A thick complex of sandstone and conglomerate occupies the area immediate north of volcano Hakone and between the Yamakita and Suruga station on the Tôkaidô railway line. Dr. T. Hirabayashi[20] who studied this formation in 1896 in connection of his geological research of the volcano Hakone, called it the Ashigara Tertiary (Asigara Tertiary) and some more detailed accounts of it was subsequently given by the late Tetsunosuke Katô[21] in his paper "Report of the geology of the vicinity of Yamakita" (in Japanese) published in the Bulletin of Imperial Geological Survey of Japan, No. 18, 1910. In 1926, Dr. M. Yokoyama[22] examined the fossil shells from this formation and expressed that the

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[18] J. Makiyama, *op. cit.*, (1927), 5.

[19] Y. Chitani, *Expl. Text Geol. Map Japan*, "Sagara" sheet, 1:75.000, (1927).

[20] T. Hirabayashi, "Geologic Report of Hakone and Atami", *Shinsai Yobô Chôsakai Hôkoku* (*Report of the Imperial Earthquake Investigation Committee in Japanese Language*), **16** (1896).

[21] Te. Kato, "The Geologic Report near Yamakita, Sagami Province", *Bull. Imp. Geol., Surv.*, Japan, **18** (1910).

[22] M. Yokoyama, "Neogene Shells from Kôzuke and Other Provinces," *Jour. Fac. Sci. Imp Univ.*,Tôkyô, Sect. II, **1**, 7 (1926).

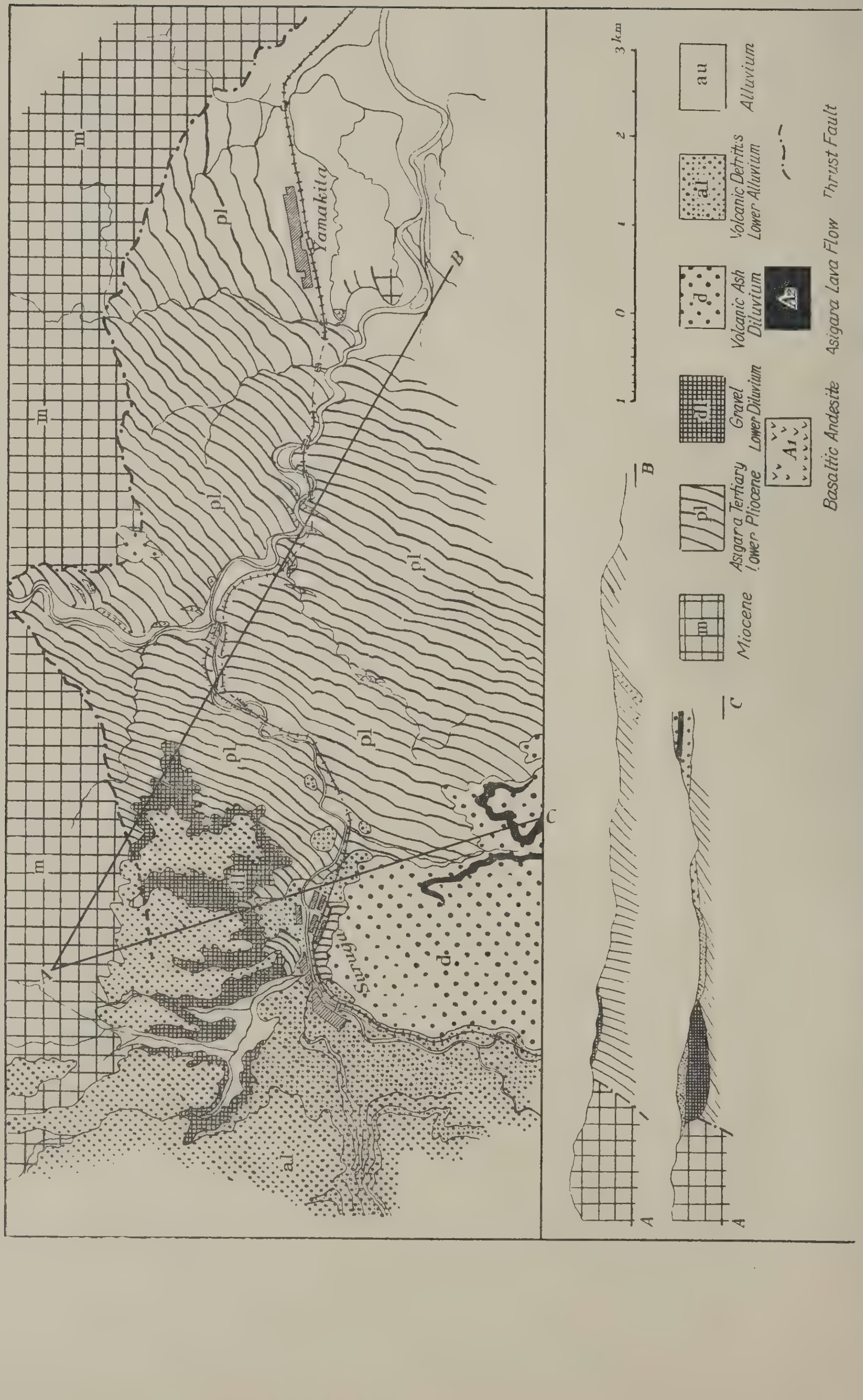

Fig. 4. Geological Map and Profiles of the Asigara District by Yanosuke Ōtuka.

fauna, which is by no means rich in species, is certainly Pliocene in age. The "Asigara Tertiary" or better Asigara beds turn the strike from E–W in the northeastern part of the field to N 10° E–10° W in the southeastern part, the dip being almost always northwestern. Previous authors ascribed this deformation of strata to a tectonic disturbances of the late Pliocene. On the north this formation lies beneath the Miocene

Table I.

List of Fossils from the Asigara beds	a. Yôzawa b. Yagurazawa c. Yaga		
1. *Acila mirabilis* Adams et Reeve	a	b	c
2. *Yoldia lischkei ?* Smith			c
3. *Yoldia* sp.	a		
4. *Glycymeris yessoensis* (Sowerby)		b	
5. *Ostrea gigas* Thunberg	a		
6. *Pecten* sp.		b	
7. *Thracia* sp.		b	
8. *Miltha* (*Lucinoma*) *annulata* (Reeve)	a	b	
9. *Diplodonta japonica?* Pilsbry			c
10. *Cardium braunsi* Tokunaga		b	
11. *Cardium* (*Fulvia*) sp.	a		
12. *Paphia ?* sp.		b	
13. *Macrocallista pacifica* (Dillwyn)	a		c
14. *Chamaeformis meretrix* Linné		b	
15. *Dosinia japonica troscheli* Lischke	a	b	c
16. *Macoma nasuta* (Conrad)	a		
17. *Tellina* aff. *gratiosa* (Römer)	a		
18. *Tellina nitidula* Dunker	a		
19. *Solen krusensternii* Schrenck	a		
20. *Mactra sulcataria* Reeve	a		
21. *Mya* aff. *japonica* A. Adams	a		
22. *Panope japonica* A. Adams	a		
23. *Turritella* sp.		b	
24. *Neritaeformis didyma* (Bolten)	a		
25. *Terebra bifrons* Smith	a		
26. *Umbonium suchiense* Yokoyama	a		
27. *Cancellaria spengleriana* Dunker	a		
28. *Lingula hians* Swainson	a		
29. *Carpinus yedoensis ?* Maximoviczi	a		
30. *Salix* sp.	a		
31. *Phyllites* sp.	a		

Misaka series overthrusted from the north upon it. Simultaneous with and also after these movements basaltic andesites intruded into it as dykes or intrusive sheets. The area of the Asigara beds is bordered by Pleistocene volcanic deposits elsewhere than north.

Fig. 4 is a geological map of the field now in question showing the structural relations of the Asigara beds to the other formations.

In the last winter I had an opportunity to collect fossils in the Asigara beds and obtained the species listed above (Table I) some of whith are additional to Dr. M. Yokoyama's[23] list.

One of these species, *Umbonium suchiense* Yokoyama, is a characteristic fossil of the lower part of the Lower Kakegawa series and is a lower Pliocene form in the evolutional series of its phyllum after Dr. J. Makiyama's scheme.[24]

Now in the Ôiso block northeast of the volcano Hakone, the Takatoriyama conglomerates,[25] which are the eastern extension of the Asigara beds, are covered by the middle Pliocene Nisikoiso[26] beds and the upper Pliocene Ninomiya beds in clinounconformity. Consequently the process which disturbed the Asigara beds must be accepted as having been active in the latest stage of the lower Pliocene, and this is in strong contrast with what we find in the Neogene strata of the Outer Zone of Southwest Japan.

5. The Nagano prefecture.

Tertiary deposits in the northern part of the Fossa Magna in the Nagano prefecture have recently been studied by Mr. F. Homma[27] in some details; his Sigarami and Ogawa beds too are regarded by Dr. M. Yokoyama[28] to be lower Pliocene in age on the molluscan fauna they contain, and Dr. S. Tokunaga[29] described once a *Cervus* remain of an upper Miocene type derived from either of them, whereas Dr. J. Makiyama[30] holds an eclectic view slightly diverging from those of the two authors, refering one complex to the upper Miocene and the other to the lower Pliocene.

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[23] M. Yokoyama, *op. cit.*, (1926), 230.

[24] J. Makiyama, "The Evolution of *Umbonium*", *Jap. Jour. Geol. Geog.*, 3-4 (1924).

[25] Y. Ôtuka, "A Stratigraphical Study of the Ôiso Blocks and Its Adjacent Area," *Jour. Geol. Soc.*, Tôkyô, **36**, **434** (1929).

[26] Y. Ôtuka, "On the Ôiso Bed," *Jour. Geol. Soc.*, Tôkyô, **33**, **451** (1931), (in Japanese).

[27] F. Homma, "Shinano Chûbu Chishitsushi (Geology of the Middle Part of Sinano Province)," (1931), (in Japanese).

28 M. Yokoyama, "Tertiary Mollusca from Shinano and Echigo". *Jour. Fac. Soc. Imp. Univ.*, Tôkyô, Sect. II, 1, **1** (1925).

[29] S. Tokunaga, "A New Form of *Cervus* from the Tertiary of Shinano", *Jour. Goel. Soc.*, Tôkyô, **33** (1926), 397-402, (in Japanese).

[30] J. Makiyama, "Preliminary Report of Tertiary Fossils from Minauchi-gôri, Shinano Province," *Chikyû*, **8** (1927), 181-188, (in Japanese).

According to Mr. Homma, these two complexes form an anticlinorium, which is intruded by the pyroxene andesites, and the main folds are parallel to the trend of the Fossa Magna, which runs in N 30° W across the Honsyû. These folds are arranged in échelon along the eastern side of the Itoigawa-Siduoka line of Dr. H. Yabe,[31] by which the southern ends of each fold are separated from the pre-Tertiary formation on the west of the tectonic line. In this part the Itoigawa-Siduoka line is a series of thrust faults. Fig. 5 CD is a geological profile, after Homma, of this district normal to the main trend.

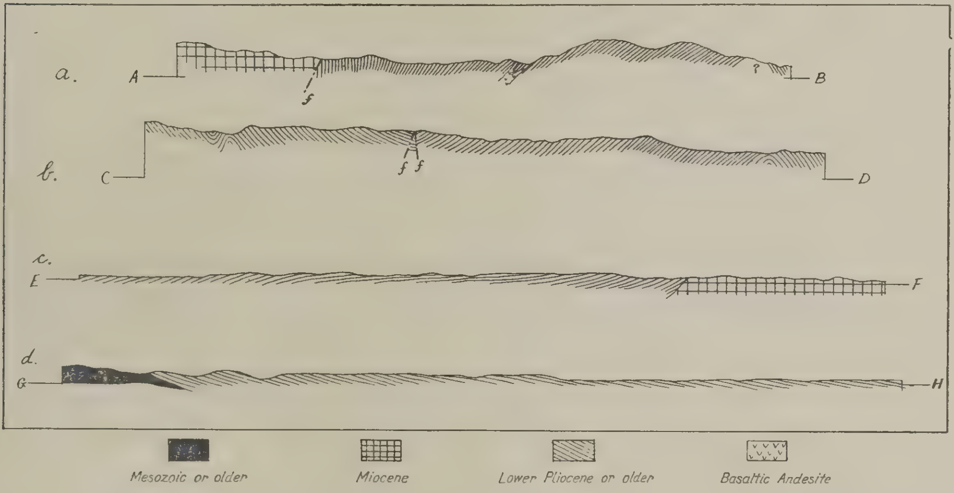

Fig. 5. Geological Profiles at Right Angles to the Strikes of the Lower Pliocene Strata. *a*, through the Asigara beds (AB = N 40°W); *b*, through the Sigarami and Ogawa beds (after F. Homma) (CD = N 75° E); *c*, through the lower Kakegawa series (after Chitani and Makiyama) EF = N 65° W); *d*, through the Takanabe group (GH = N 70° W). *f* = faults.

The results of the previous descriptions of the Pliocene deposits of the five districts may be summarized as follows :—

1. Stratigraphically the Pliocene deposits of the five districts cited above are to be correlated as follows (Table II).

2. In the latest stage of lower Pliocene, crustal movements took place in Japan. In the Outer Zone of Southwest Japan, the lower Pliocene or

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[31] H. Yabe, "Itoigawa-Siduoka Geotectonic Line", *Gendai no Kagaku*, **6**, 3 (1918), (in Japanese)

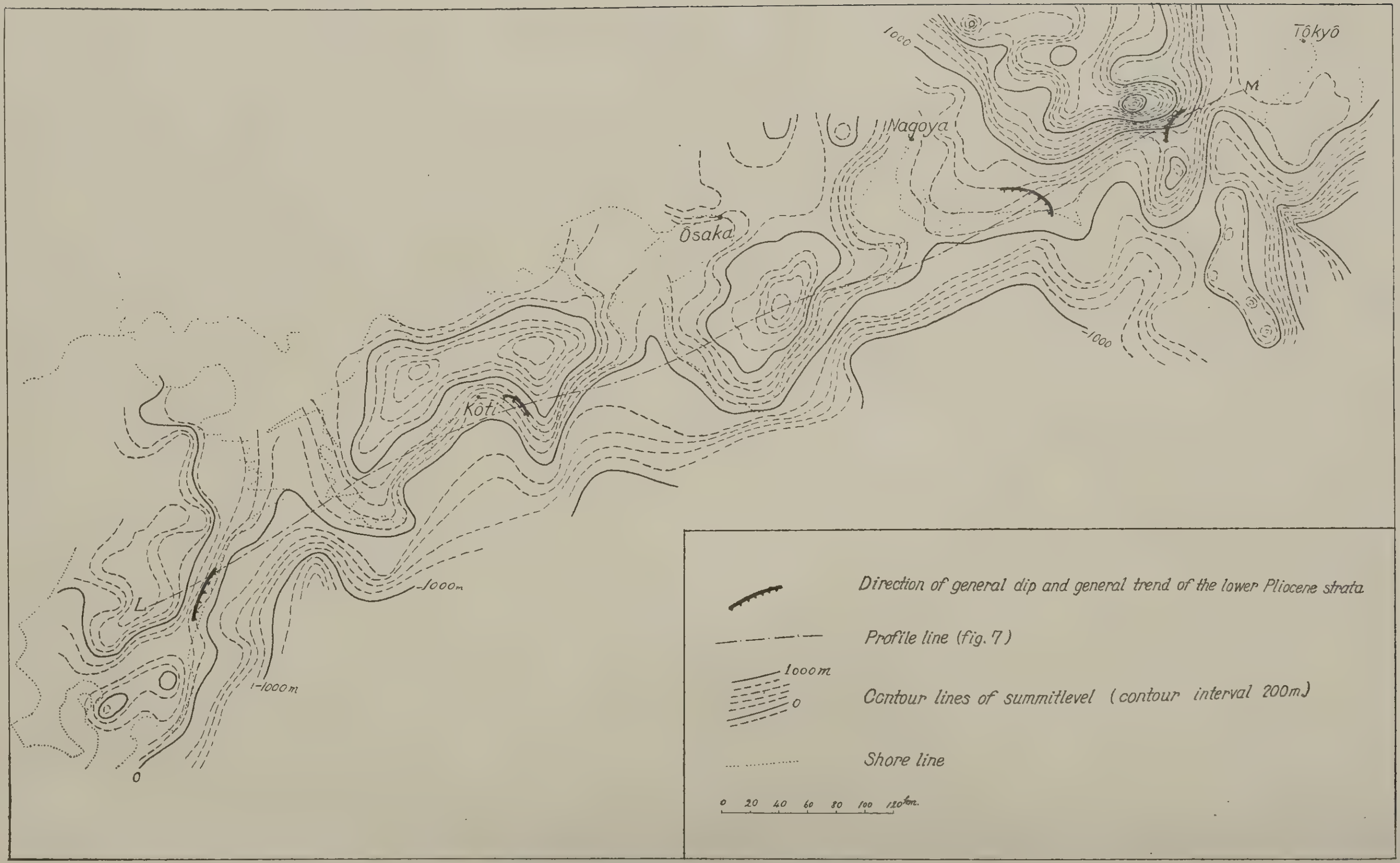
Tōkyō
M
Nagoya
Ōsaka
Kōti
L
1000
1000
1000m
1-1000m
0
Direction of general dip and general trend of the lower Pliocene strata
Profile line (fig. 7)
1000m
0
Contour lines of summitlevel (contour interval 200m)
Shore line
0 20 40 60 80 100 120 km.

Fig. 6. Summit-level of Southwest Japan.

Table II.

Geologic Age \ Locality	(1) Miyazaki	(2) Kôti	(3) Kakegawa	(4) Asigara	(5) Nagano
Upper Diluvium	Gravel beds	Gravel beds	Gravel beds	Volcanic lava and ash	
Lower Diluvium	Freshwater deposits		Ogasa conglomerate	Gravel beds	
Upper Pliocene			Soga beds	(Ninomiya beds) Nisikoiso beds	
Lower Pliocene	Takanabe group { Heki beds Kôonzi beds Sadowara beds	Suzuki's Pliocene *Umbonium mysticum* Zone	Kakegawa series Horinouti series	Asigara beds	Sigarami beds Ogawa beds
Miocene	Tuma group		Sagara beds	Misaka beds	

Pliocene strata are usually monoclinal in low angles either to southwest, or to south with a few exception of other small displacements, while the contemporaneous deposits in the Fossa Magna form a complex anticlinorium, each pericline with the trend parallel to that of the Fossa Magna. There are many thrust- and normal-faults in association of these folds, and volcanism was often active.

3. The structural lines of the lower Pliocene deposits do not conform with the general trend of the Honsyû arc or with the main structural lines of the Outer Zone of Southwest Japan, but with the trend of contour lines of a summit level in the Outer Zone of Southwest Japan. Fig. 6 is a map showing the conformity of the structural lines of the lower Pliocene strata and the trend of contour lines of the summit-level.

4. Fig. 7 is a schematic profile from Siduoka through the Tosa bay to Miyazaki along the line LM in fig. 6. That is parallel to the main structural trend of the Outer Zone of Southwest Japan. It shows us that the inclination of the bedding plane of the Pliocene strata is steeper than that of the surface of the summit-level dipping to the same direction ; and suggests that an extensive crustal movement in the form of broad swells took place in the Outer Zone of Southwest Japan along the lines rather parallel to the Ryûkyû arc than to the Honsyû arc

5. Comparing the thickness and rock facies of these lower Pliocene strata, the Fossa Magna may be regarded as a geosynclinal trough of the geological period.

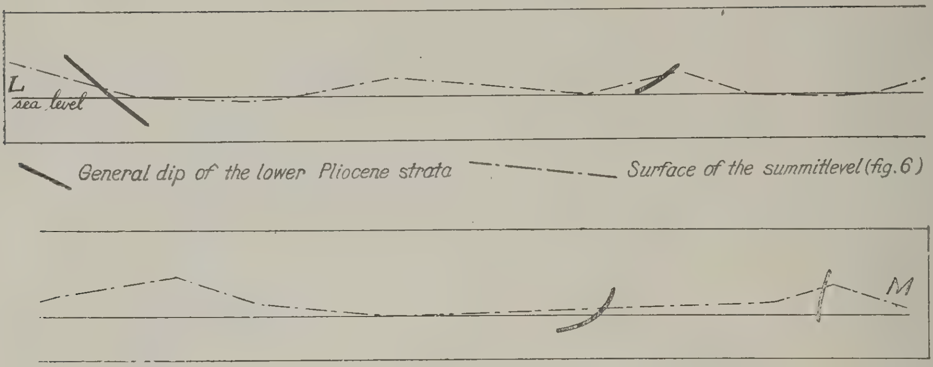
L
sea level
General dip of the lower Pliocene strata
Surface of the summitlevel (fig. 6)
M

Fig. 7. Profile along L : in Fig. 6. Vertical scale × 5

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24. 西南日本外帶とフォッサ・マグナとに於ける鮮新期初期末の地殻運動

地震研究所 大塚彌之助

西南日本外帶とフォッサ・マグナとの下部鮮新統の發達地域五ケ處（宮崎縣日向海岸平野、高知縣東部土佐灣沿岸、靜岡縣掛川地方、靜岡神奈川兩縣下足柄地方、長野縣北部）の地質を略記し、それらの地質構造の一般的特徴を述べ互に比較した。

その結果次のやうなことが知られた。

鮮新期初期末に著しい地殼運動が日本に起つた。その擾亂の程度はフォッサ・マグナに於て極めて著しく、褶曲、正逆斷層、火山活動等が生じた。外帶ではその程度が極めて弱く展張性を帶びてゐた。陸地測量部の五萬分ノ一地形圖一枚の面積を一單位として作つた切峯面と下部鮮新統の構造とを比べてみると、下部鮮新統の層向の走向とその地域の切峯面の等高線の走向とはかなり一致し、その地層の傾斜の度は、その地域の切峯面の傾斜の度より急であるが、その方向は一致してゐる、又地層の厚さはフォッサ・マグナの地域の鮮新統の方が厚い。

上記の事實から鮮新期初期末に起つた地殼運動は極めて激しかつたやうだが、西南日本外帶では展張性な廣い「うねり」があつたやうにも見える。そしてその「うねり」の峯の延び方は琉球弧に平行なものの方が、本州弧に平行なものに比べて著しく目について見える。尙フォッサ・マグナはヂォシンクラインであつたらしい。

25. *Petrographic Notes on the Sedimentary Rocks of Southwest Sagami Province. (Part II)*

By **Hiromichi TSUYA**,

Earthquake Research Institute.

(Read Jan. 20, 1931.—Received June 20, 1931.)

Introduction.

In a previous paper[1] the writer gave results of his petrographic study of the sedimentary rocks of Enosima[2], and showed that, petrographically, the rocks there have certain distinguishing characters according to their respective stratigraphic horizons.

This is a continuation of that paper and gives results of petrographic studies of the rocks of Ôiso[3], a district adjoining the northeast foot of volcano Hakoné[4], in Idu. The rock-specimens examined were not sufficient for the purpose of this study, so that publication of full results will have to be deferred to a later opportunity. Many of the rock-specimens were supplied by Y. Ôtuka[5], who is studying the geology of the district from the stratigraphic side, and to whom the writer tenders his sincere thanks.

Stratigraphic Succession of the Beds of Ôiso District.

Stratigraphic studies of the district have been made by several geologists. It being however outside the scope of this paper, the reader is referred to Ôtuka's paper[6], for a summary of it, in which a bibliography of earlier literature on the subject will also be found. Recently, Y. Ôtuka[7]

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1) H. Tsuya, "Petrographic Notes on the Sedimentary Rocks of Southwest Sagami Province, (Part I.)," *Bull. Earthq. Res. Inst.*, 9 (1931), 98–106.

2) 江ノ島

3) 大磯

4) 箱根

5) Y. Ôtuka, "A Stratigraphical Study of the Ôiso Block and Its Adjacent Area," *Jour. Geol. Soc.*, Tôkyô, 36 (1929), 435–456; 479–497, (in Japanese).

6) Y. Ôtuka, *loc. cit.*

7) Y. Ôtuka, "On Ôiso Bed," *Jour. Geol. Soc.*, Tôkyô, 38 (1931), 174–187, (in Japanese).

made a revision of the stratigraphy of the district. According to his revised summary, the stratigraphic succession is as shown in Table I, and the distribution of the successive beds as shown in Fig. I.

Table I.

Geol. Periods		Beds	Rock types
Holocene	a_{II}		Dune-sands; fluviatile deposits of sands, gravels, and clay.
	a_{I}	Simohara[8] bed	Fossiliferous deposits of sands and gravels.
Pleistocene	du_{II}	Terrace bed	Gravels.
	du_{I}	Loam bed Takao[9] bed	Volcanic ashes ? and lapilli. Andesitic pumices and andesitic tuffs.
	dl_{II}	Kuroiwa[10] bed	Andesite-gravels, and others.
	l_{I}	Tutizawa[11] bed	Fossiliferous sands and clay; dacitic tuffs.
	p-d	Ninomiya[12] bed	Fossiliferous, tufaceous sands.
Pliocene	pu pm	Nisikoiso[13] bed	Fossiliferous conglomerate.
	pl	Takatoriyama[14] bed	Andesite-gravels; andesite agglomerates and lavas.
Miocene	mu ml	Ôiso bed	Fossiliferous, tufaceous sandstone and conglomerate.
	o?	Komayama[15] bed	Dacite-dikes and lavas; dacitic tuffs. Siliceous sandstone.

Volcanic History as inferred from Petrographic Studies.

As shown in Table I, the general geologic succession of the district consists of an alternation of pyroclastic rocks and sedimentary rocks containing much volcanic material. These rocks belong to their respective stratigraphic divisions, the lowest one of which dates back to the lower Miocene or probably an older period. If they contain juvenile

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8) 下原 9) 高尾 10) 黑岩 11) 土澤 12) 二宮 13) 西小磯 14) 鷹取山 15) 高麗山

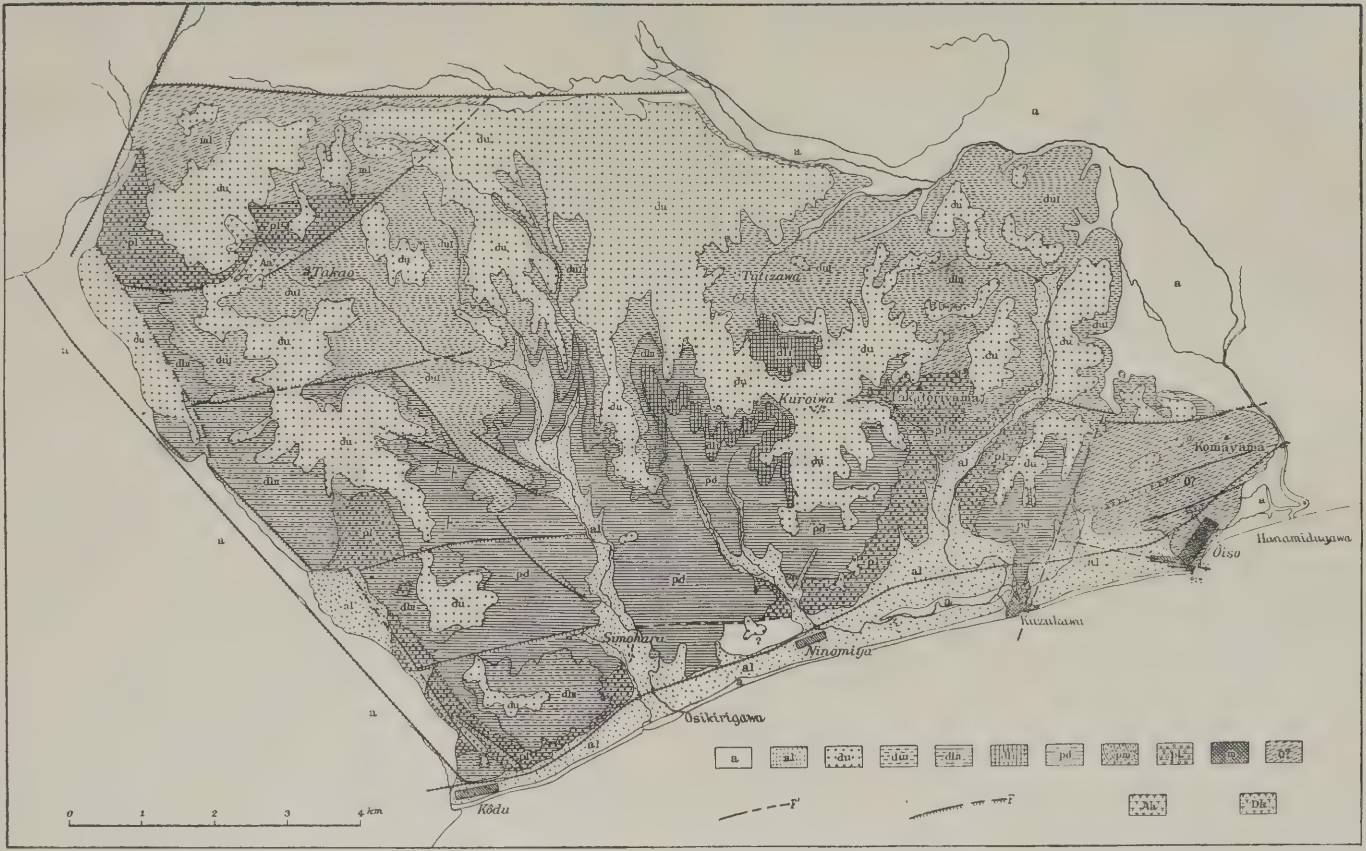

Fig. 1. Geologic map of the Ôiso district. (after Y. Ôtuka, 1931.) a—Alluvium, al—Simohara bed, du—Loam bed, du$_{I}$ —Takao bed, dl$_{II}$—Kuroiwa bed, dl$_{I}$ – Tutizawa bed, pd—Ninomiya bed, pm—Nisikoiso bed, pl –Takatoriyama bed, m—Ôiso bed, o?—Komayama bed, Aa—Pyroxene-andesite, Da—Dacite. F, F'—Faults.

volcanic material that were ejected from volcanoes during their respective geologic periods, then the volcanic history of the district since the lower Miocene or even of a still older period can be inferred from a petrographic study of these material.

Many of the pyroclastic rocks are of subaqueous deposition, as indicated by occasional occurrences of marine and fresh-water fossils. In these rocks, therefore, occur detritus, either volcanic or non-volcanic; but they all consist of practically the same volcanic material, possessing certain distinguishing characters as petrographic studies will reveal. These rocks are

$\mathrm{du_I}$.	Andesitic tuffs and andesitic pumices	Takao bed.
pl.	Andesitic agglomerate	Takatoriyama bed.
o ?	Dacitic tuffs	Komayama bed.

In addition to these, dacite and andesite occur as lavas, respectively, in the Takatoriyama bed and the Komayama bed. Consequently, there is little question that these rocks represent the volcanic activities of their respective geologic periods.

The ordinary sedimentary rocks of the district contain sundry volcanic material in various proportions. They are

$\mathrm{dl_{II}}$.	Andesite gravels	Kuroiwa bed.
$\mathrm{dl_I}$.	Tufaceous sands and clay	Tutizawa bed.
p-d.	Tufaceous shale	Ninomiya bed.
pu.	Conglomerate	Nisikoiso bed.
mu. ml.	Tufaceous sandstone and tufaceous conglomerate	Ôiso bed.
o?.	Siliceous sandstone	

Although some explosive volcanic material, either juvenile or accessory, may occur, most of the volcanic material in these rocks are regarded as detritus arising from the weathering, disintegration, and transport of pre-existing volcanic masses. Until some of the volcanic material are proved to have been of juvenile origin at the time of their respective depositions, these rocks have no bearing on the present discussion. To determine what is juvenile and what is accessory or detrital in the volcanic material contained in such rocks is generally not an easy matter.

The gravels of the Kuroiwa bed contain much angular blocks of porous olivine-augite-andesite which, according to Y. Ôtuka(16), are sugges-

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16) Y. ÔTUKA, *loc. cit.*, 480.

tive of eruption at the time of their deposition. The tufaceous sands and clay of the Tutizawa bed are mixed with much pumice. These deposits pass upward into a finely stratified bed consisting entirely of pumice. Occasionally, the pumice exhibits oxidation effects, as was observed in juvenile pumiceous ejecta at the time of the eruption in 1929 of Komagataké (Hokkaidô[17]). These effects might be due to high temperatures that were maintained at the time of ejection for periods sufficiently long to bring about oxidation. These facts suggest juvenile origin for the pumice. But with the exceptions of the Kuroiwa bed and the Tutizawa bed, evidence in the district of juvenile origin for some of the volcanic constituents of the above-mentioned sedimentary rocks is entirely wanting. In the circumstances, volcanic history of the district can be inferred only partially from petrographic study. The history as far as can be traced is as follows:

Of beginning of volcanic activity during the Tertiary in the neighbouring district of Idu no trace is found in the Ôiso district; nor is there any certainty that the volcanic material (Hypersthene-augite-andesine-andesite, see p. 363) in the siliceous sandstone (o? in Table I) marks the oldest volcanic activity in the Ôiso district.

From all reliable data obtainable, volcanic activity begun before the Miocene, with eruptions of dacitic lavas and tuffs (Komayama bed, o? in Table I) which were followed by intrusions of dacite-dikes. From their calcareous nature, the dacitic tuffs seem, locally at any rate, of submarine deposition. The micro-cataclastic structure exhibited in the tuffs may be the result of later disturbances, which, according to Y. Ôtuka, threw the tuffs into complicated structures with numerous fault systems. This was followed by renewed outpourings of lava and agglomerate, but this time of more basic type, such as the two-pyroxene-bytownite-andesite (see p. 367) of the Takatoriyama bed (pl in Table I). The volcanic material in the Ôiso bed (ml-mu in Table I) and Nisikoiso bed (pm-pu in Table I) are, petrographically, of the same general type as those in the Takatoriyama bed (see pp. 367–368). Furthermore, the volcanic constituents of the Ninomiya bed (p-d in Table I) are indistinguishable from those of beds previously mentioned (see p. 369). If therefore some of the volcanic material in these three beds—the Ôiso, the Nisikoiso, and the Ninomiya beds—were of juvenile origin at the

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17) S. Tsuboi and H. Tsuya, "On the Temperature of the Pumiceous Ejecta of Komagataké, Hokkaidô, as inferred from their Mode of Oxidation," *Bull. Earthq. Res. Inst.*, 7 (1930), 271–273.

time of their respective depositions, it may be said that volcanic activity of the same general type as that represented by the pyroxene-andesite in the Takatoriyama bed occurred during the periods between the lower Miocene and the lowest Pleistocene.

After the formation of the Ninomiya bed there was a reversion in the eruptions to rocks of more acidic character (Tutizawa bed, dl_I in Table I). This is seen in the dacitic tuff which consists of quartz, hornblende, hypersthene, augite, and labradorite, together with pumice and obsidian (see p. 369 .

Basic andesites characterized again the subsequent volcanic activities as is seen by the fresh blocks of olivine-augite-anorthite-andesite (see p. 370) in the Kuroiwa bed (dl_{II} in Table I) and also by the pumice of both hypersthene-augite-bytownite-andesite and hypersthene-augite-labradorite-andesite (see p. 371) in the Takao bed (du_I in Table I).

The last volcanic activity traceable in rocks of the district seems to be represented by the scoriaceous lapilli of augite-bytownite-andesite (?, see p. 372) in the so-called loam bed.

Comparison of Rocks of the Ôiso District with Similar Rocks of the Adjoining District.

Of centres of the above-mentioned volcanic activities, and which supplied the pyroclastic material now found in the rocks of Ôiso district, there is no trace there today. These centres may however be located in the adjoining districts where volcanic rocks occur. They are Asigara[18] on the northwest and Idu[19] on the southwest. The rocks of these two districts are of the same general type, but naturally differ in detail. It is believed that careful comparison of the rocks of Ôiso district with those of neighbouring districts may throw some light on their genetical relationship. For this purpose, further detailed studies of rocks of neighbouring districts are desirable. The following comparison is only tentative.

1. *Siliceous sandstone* (o? in Table I) and *tufaceous sandstone*[20] *in the lower Miura series of Enosima.*

The former is similar in mineral composition to the latter, both being composed of quartz, orthoclase, andesine ($Ab_{60}An_{40}$), hornblende,

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18) 足柄

19) 伊豆

20) H. TSUYA, *loc. cit.*, 99.

and augite, together with microscopic fragments of pyroxene-andesite (see p. 363). The main difference is that the former is siliceous with much quartz fragments while the latter is tufaceous with much andesite fragments. Although their stratigraphic relation is yet uncertain, they are considered to be older than lower Miocene.

2. *Dacite of the Komayama bed* (o? in Table I) and *dacitic rocks*[21] *of Idu district.*

The acidic rock that occurs as dikes intruding into the dacitic tuffs of the Komayama bed is hypersthene-hornblende-labradorite-dacite (see p. 364). In the Idu district liparitic and dacitic rocks occur in following sequences:

Idu Peninsula[22],

Potash-liparite → biotite-plagioliparite → hornblende-dacite → augite-hornblende-dacite → hypersthene-hornblende-dacite → two-pyroxene-dacite.

Niizima[23] group of the Seven Idu Islands[24],

Potash-liparite → pyroxene-plagioliparite → hornblende-plagioliparite → biotite-plagioliparite.

In Table II is shown a comparison of the refractive indices of the

Table II.

	Plagioclase	Hornblende (n_{1D})	Augite	Hypersthene (n_{1D})
I	$Ab_{45}An_{55}$	1·6721	n.d.	1·6991
II	$Ab_{62}An_{38}$	1·6748	—	—
III	$Ab_{55}An_{45}$	1·6783	n.d.	—
IV	$Ab_{62}An_{38}$	1·6915	—	n.d.
V	$Ab_{64}An_{36}$	—	n.d.	1·6997

I. Hypersthene-hornblende-labradorite-dacite, Ôiso.
II. Hornblende-andesine-dacite, Takaneyama, Simoda, Idu[25]
III. Augite-hornblende-andesine-dacite, Warabo, Idu[26].
IV. Hypersthene-hornblende-andesine-dacite, Taga, Idu[27].
V. Augite-hypersthene-andesine-dacite, Kasiwatôgé, Itô, Idu[28].

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[21] H. Tsuya, "Volcanoes of Kôzu-shima," *Bull. Earthq. Res. Inst.*, 7 (1929), 318–339.
[22] 伊豆半島 [23] 新島 [24] 伊豆七島
[25] 伊豆下田高根山 [26] 伊豆原保 [27] 伊豆多賀 [28] 伊豆伊東柏峠

constituent minerals in some dacitic rocks of Idu district and the dacite of the Komayama bed. The principal difference between the dacite of the Komayama bed and the similar rocks of the Idu district is in the more calcic composition of the plagioclase phenocrysts of the former and in the lower refractive indices of the phenocrystic mafic minerals of the former.

Stratigraphically, the liparitic or dacitic rocks of the Idu district, in view of their geologic ages, may be left out of consideration. As far as the writer knows, they are believed to be younger than lower Miocene, whereas, according to Y. Ôtuka, the dacite and dacitic tuffs of the Komayama bed are of lower Miocene or probably an older period. But, volcanotectonically, the N.E.-S.W. trend of distribution of the liparitic and dacitic rocks of the Idu district is very significant in connection with the same trend noticeable in the strike, the fault systems, and in the dacite-dikes in the Komayama bed. Probably, this trend is a surface manifestation of the regional structure of the ground, and the cause of the eruption here of liparitic and dacitic rocks throughout recent geologic time.

3. *Andesitic material in the rocks of Ôiso district* and *similar material in the rocks of the neighbouring districts.*

Petrographically, the andesitic material of the Ôiso bed, the Takatoriyama bed, the Nisikoiso bed, and of the Ninomiya bed are of the same general type as the constituents of the agglomerate-tuff of the upper Miura series of Enosima. The former is also of the same general type as the andesitic material of the Asigara bed of Asigara district. But of stratigraphic relations between them, petrographic study has not yielded so far any evidence. The andesitic material of the Kuroiwa bed and of the Takao bed are similar to the basaltic andesite of the volcanoes, Hakoné, Amagi[29], etc., of the Idu district. Probably, the depositions of the former and the eruptions of the latter took place at the same general time, in middle and upper Pleistocene, when the nature of the magma regionally became strongly basic[30].

4. *Dacitic tuff of the Tutizawa bed* (dl_I in Table I) and *similar rock of the Simo-Tanna*[31] *bed of Idu district.*

The occurrence of dacitic material (see p. 369) in the Tutizawa bed calls for a discussion of their possible relation to similar material in the

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[29] 天城
[30] S. Tsuboi, "Volcano Ô-shima, Izu," *Jour. Col., Tôkyô Imp. Univ.*, 43 (1920), 139.
[31] 下丹那

Simo-Tanna bed of northern Idu. The Simo-Tanna bed develops at the western margin (Simo-Tanna) of the Tanna basin[32], under which the so-called Tanna tunnel is now being excavated. It consists of sandy tuff, tufaceous shale, and black clay. The sandy tuff contains many fragments of hornblende-pyroxene-dacite, as well as of pyroxene-andesite. The dacite is pumiceous and is similar in the refractive indices of the constituent minerals to the dacitic material in the tuff of the Tutizawa bed, as shown in Table III.

Table III.

	Glass (n_D)	Quartz	Plagioclase	Hornblende	Augite (n_{1D})	Hypersthene (n_{1D})
I	1·5083	+	$Ab_{45}An_{55}$	n_{1D} 1·6617 n_{2D} 1·6737	1·6930	1·7040
II	1·5075	+	$Ab_{43}An_{57}$	n_{1D} 1·6617 n_{2D} 1·6757	1·6930	1·7040

I. Dacitic tuff, Tutizawa bed, Ôiso.
II. Dacite pumice, Simo-Tanna bed, Idu.

Evidences of fresh-water deposition are found both in the Tutizawa bed and in the Simo-Tanna bed. The Tutizawa bed contains "*Corbicula nipponensis* Prim." and "*Juglans sieboldiana* Max.[33]" It contains also brown coal containing plant fossils. The black clay in the Simo-Tanna bed contains plant fossils.

The Tutizawa bed was subjected to a crustal movement with considerable tilting and minor faulting. It is overlain by the Takao bed which practically consists of angular blocks of olivine-pyroxene-andesite. The Simo-Tanna bed was disturbed by faulting, tilting, and flexuring. It is covered with lavas and fragmentals of olivine-pyroxene-andesite.

The above-mentioned similarities, petrological, palaeontological, and structural, suggest that the Tutizawa bed and the Simo-Tanna bed are of the same age. If these beds are entirely of detrital origin, it would then be a rare coincidence that they are similar to each other in mineral composition. But they contain dacitic pumice which suggests juvenile ejecta (see p. 370), besides many isolated crystals similar to those in the pumice. Therefore, it would seem far more reasonable to conclude that both of them had received their share of dacitic juvenile ejecta at the same time from a certain volcanic centre that happened to be active at the time of their deposition in the Pleistocene period. It is to be noted that dacitic volcanism displayed activity in the northern Idu in the Pleistocene period.

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[32] 丹那盆地

[33] Y. Ôtuka, *loc. cit.*, 455–456.

5. *The so-called loam of Ôiso district* and *similar rocks in other localities.*

The material composing the so-called loam bed of the Ôiso district is almost destitute of microscopically determinable minerals except plagioclase and augite, which are very rarely found in the scoriaceous lapilli layers in the loam bed. The writer in his previous paper[34] suggested that the material composing the loam bed of Enosima may be of detrital origin. These beds are distributed widely in the Kwantô district, and are included stratigraphically in the name "Kwantô Loam". Petrographically, they show much variation, laterally as well as vertically. In Table IV. are shown the results of optical analyses of the minerals found in some specimens of this loam.

Table IV.

	Orthoclase	Plagioclase	Augite (n_{1D})	Hypersthene (n_{1D})
I	–	$Ab_{13}An_{87}$	1·6922	–
II	–	$Ab_{30}An_{70}$	1·6920	–
III	–	$Ab_5 An_{95}$	–	–
IV	+	–	1·6970	1·6899
V	–	$Ab_{78}An_{22}$	1·6937	–
VI	–	$Ab_{35}An_{65}$	1·6925	1·6940

I. Isolated crystals in lapilli in loam bed, Sibusawa[35], Ôiso.
II. Isolated crystals in the upper horizon of the loam bed, Enosima.
III. Isolated crystals in the lower horizon of the loam bed, Enosima.
IV. Isolated crystals in the lower part of the middle horizon of the loam bed, Masukatayama, Noborito[36].
V. Isolated crystals in the upper part of the middle horizon of the loam bed, Ibid.
VI. Isolated crystals in the loam bed, Ikégayato, about 5 km. southeast of Hatiôzi[37].

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[34] H. TSUYA, *loc. cit.*

[35] 澁澤 [36] 登戸桝形山 [37] 池ヶ谷戸，八王子.

Petrographic Descriptions of the Rocks of Ôiso District.

The petrographic descriptions of typical rocks of the Ôiso district are given in the following order:

I. Siliceous sandstone (o? in Table I.)
II. a. Dacitic tuffs
    b. Dacite (Komayama bed.)
III. Tufaceous sandstone (Ôiso bed.)
IV. Pyroxene-andesite (Takatoriyama bed.)
V. Conglomerate (Nisikoiso bed.)
VI. Tufaceous shale (Ninomiya bed.)
VII. Dacitic tuff (Tutizawa bed.)
VIII. Olivine-augite-andesite (Kuroiwa bed.)
IX. Two-pyroxene-andesite (Takao bed.)
X. Loam (Loam bed.)

I. ***Siliceous sandstone*** (o? in Table I.) (Fig. 2.)

This rock occurs at Takatoriyama, about 1 km. northeast of Ôiso railway station on the Tôkaidô line, forming the foundation of the Takatoriyama bed. It occurs with siliceous shale.

Megascopic Characters.—The rock is light gray to green, medium-grained, and is compact. Visible in it are crystals, 1·0–1·5 mm. in diameter, of quartz, felspar, hornblende, and pyroxene.

Microscopic Characters.—This rock is composed of quartz, plagioclase, orthoclase, hornblende, hypersthene, augite, and magnetite, together with a few fragments of augite-andesite. Although these constituents are commonly angular to subangular, they are sometimes well rounded.

The quartz, 0·1–1·0 mm. in diameter, is not cracked, but is pure and free from any notable inclusions.

The plagioclase, 0·1-1·5 mm. in diameter, exhibits the simple and polysynthetic twinnings according to the Carlsbad and albite laws. The extinction angle is $Y \wedge (010) = 20°$ and the optic character of the mineral positive. The plagioclase was identified as andesine near $Ab_{60}An_{40}$. The mineral contains a few particles of dark brown glass.

The hornblende, 0·1–0·2 mm. in length, is moderately pleochroic. Its axial colors are X'—light yellowish green, Y'—deep brownish green, Z'—green. $c \wedge Z'$ (on 110) $= 14°$. The maximum extinction angle measured is 17°. The refractive indices measured with the cleavage flakes are $n_{1D} = 1{\cdot}6635$, $n_{2D} = 1{\cdot}6767$.

The hypersthene, 0·1–0·5 mm. in length, shows alteration along its cleavage lines. The augite, less than 0·1 mm. in diameter, is negligible in quantity.

The fragments of augite-andesite, 0·3–0·5 mm. in diameter, contain a few plagioclase phenocrysts scattered through the groundmass which consists of plagioclase, augite, magnetite, and a brown glass base.

Another sample of the siliceous sandstone is free from isolated crystals of hornblende and hypersthene, but it contains abundant rock-fragments, chief among which are vitreous andesite, silicified rock, and quartz-orthoclase-oligoclase-hornblende-rock.

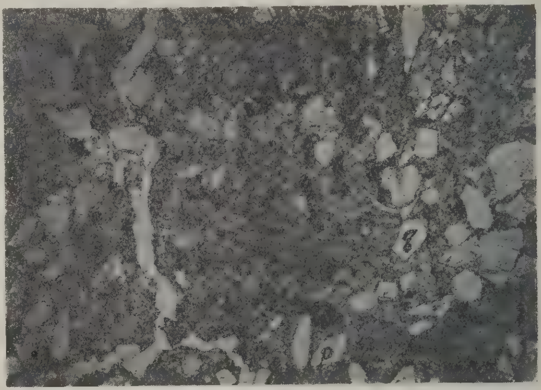

Fig. 2. Microphotograph of siliceous sandstone. × 30. p—andesine, ho—hornblende, hy—hypersthene, a—augite, q—quartz.

II. Dacitic tuffs and Dacite (Komayama bed.)
(Figs. 3 and 4.)

a. **Dacitic tuffs.** This rock occurs as disturbed strata at Komayama and its environs near Ôiso, and occurs with siliceous shale and breccia.

Megascopic Characters.—The dacitic tuffs are white. Angular fragments of plagioclase, quartz, and pyroxene are scattered through the white matrix.

Microscopic Characters.—There are two types of dacitic tuffs, the α-type and β-type.

α-type. Dacitic tuff of this type consists of plagioclase, quartz, hypersthene, augite, and colorless splinters of glass. The minerals are 0·1–1·0 mm. in diameter, quartz being the most abundant.

The plagioclase is twinned according to the albite laws. Zoning of less and more calcic plagioclases is absent. The refractive indices are $n_{1D}=1{\cdot}5573$, $n_{2D}=1{\cdot}5644$. Accordingly, the mineral was identified as labradorite $Ab_{45}An_{55}$. It contains minute inclusions of brown glass.

The hypersthene is moderately pleochroic. Its axial colors are X—yellowish green, Y—brownish green, Z—green. Optical plane parallel to the c-axis : the refractive index $n_{1D}=1{\cdot}7152$. The augite is light green. It is subordinate in amount.

The groundmass consists of angular splinters, 0·1–0·3 mm. in diameter, of pumiceous glass, perlitic glass, and light brownish obsidian. The refractive index of the pumiceous glass is $n_{1D}=1{\cdot}5070$.

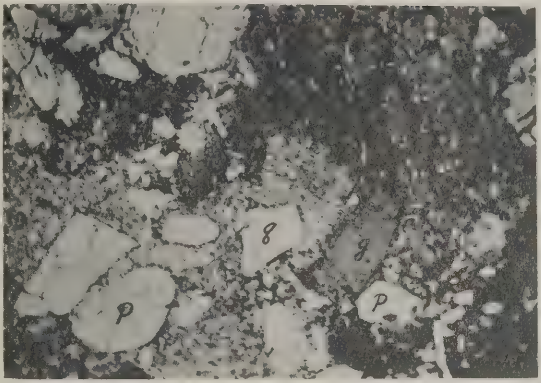

Fig. 3. Microphotograph of dacitic tuff (*α-type*). ×32. p—labradorite, q—quartz, hy—hypersthene, g—glass.

β-type. Dacitic tuff of this type consists of quartz, plagioclase, hypersthene, augite, and biotite, together with splinters of glass and a few fragments of hypersthene-andesite. These constituents are crushed into angular pieces and their interstices filled with calcite.

The plagioclase shows faint zoning of less and more calcic plagioclases. It is twinned according to the albite and Carlsbad laws. The optical character of the mineral is positive. It was identified as bytownite $Ab_{25}An_{75}$, with $n_{1D}=1{\cdot}5675$. Small particles of brown glass are included in the mineral.

The hypersthene is pleochroic. Its axial colors are X—brownish green, Y—brownish green, Z—green. Optical plane parallel to the c-axis: the refractive index $n_{1D}=1{\cdot}6998$. The augite occurs in subordinate amount as fragments of about 0·5mm. in diameter, with refractive index $n_{1D}=1{\cdot}6928$.

The biotite occurs in negligible amount as distorted flakes of about 0·5 mm. in length.

The glass splinters are obsidian with $n_D=1{\cdot}4980$. They are light brownish and contain microlites. The hypersthene-andesite, which occurs sporadically as angular fragments, 1·0–1·5 mm. in diameter, is porphyritic with phenocrysts of plagioclase and hypersthene scattered through a glassy groundmass.

b. Dacite. This rock occurs as dikes intruding into the Komayama bed.

Megascopic Characters.—The rock is white, medium-grained, and is fragile. It is percrystalline and is porphyritic with phenocrysts of quartz, plagioclase, hornblende, and hypersthene

Microscopic Characters.—The rock is sempatic to dosemic, and is composed of closely packed phenocrysts of quartz, plagioclase, hornblende, augite, and hypersthene, together with magnetite grains and interstitial glass base.

The plagioclase phenocryst, 0·5 mm. in diameter, is twinned according to the albite and Carlsbad laws. Zonal structure due to the chemical difference is exhibited. Recurrent zoning is often noticed. The less calcic shell part of the zonally built phenocryst was identified as labradorite $Ab_{45}An_{55}$ with the following optical properties: $n_{1D}=1{\cdot}5569$, $n_{2D}=1{\cdot}5620$. Extinction angle on section perpendicular to X is $Y \wedge (010)=28°$. The optical character is positive. The more calcic plagioclase (bytownite) forms the core part of the plagioclase phenocryst. Small enclosures of brown glass are arranged in zones parallel to the outline of the host mineral. The quartz, 0·3–0·6 mm. in diameter, is irregularly cracked, and has irregular outline either with rounded corner or with sharp edge. Rarely, the bipyramidal form of the mineral is incompletely developed. The mineral is almost free from inclusions except sporadic enclosures of a deep brown opaque mass.

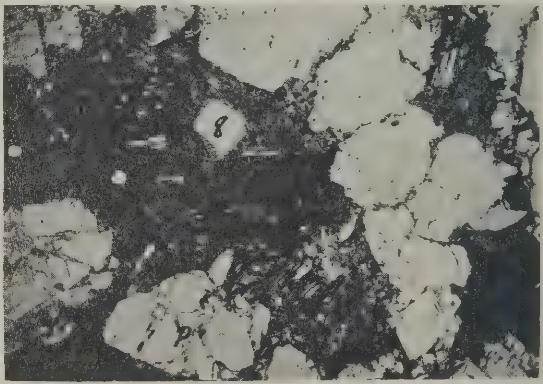

Fig. 4. Microphotograph of dacite. × 30. p—labradorite, q—quartz, ho—hornblende, hy—hypersthene.

The hornblende, 0·5–1·0 mm. in diameter, is euhedral to subhedral, but is frequently split along the prismatic cleavage lines. Lamellar twinning is often exhibited. The mineral shows a distinct pleochroism with the axial colors X′—pale greenish brown, Y′—green, Z′—dark green. Absorption $X' < Y' < Z'$: maximum extinction angle measured in thin section $c \wedge Z'=24°$: refractive indices $n_{1D}=1{\cdot}6587$, $n_{2D}=1{\cdot}6721$. The mineral contains inclusions of plagioclase.

The hypersthene, 0·1–1·0 mm. in length, occur as stout prisms, euhedral to subhedral, and shows distinct cleavage lines. Optical plane is parallel to the c-axis. The mineral is pale brown with faint pleochroism X—pale brown, Y—pale yellowish brown, Z—pale green. The refractive index $n_{1D}=1{\cdot}6991$. Enclosures are plagioclase prismoids and colorless glass. The augite, 0·1–0·5 mm. in diameter, is negligible in amount.

The groundmass is colorless glass in which are disseminated magnetite grains and plagioclase microlites. Angular fragments (1·0 mm. in diameter) of a microgranular rock and composed practically of quartz, albite, and chlorite are found though rarely.

III. ***Tufaceous sandstone*** (Ôiso bed.) (Fig. 5.)

This rock occurs at Sigitatusawa[38] and Terugasaki[39] near Ôiso as alternating layers of fine and coarse sands.

Megascopic Characters.—The rock is light gray and compact. It is porphyritic with pumiceous fragments (1·0–10 mm. in diameter) of pyroxene-andesite scattered through the tufaceous matrix in which are found plagioclase and pyroxene.

Microscopic Characters.—The rock is characterized by its numerous angular constituents, of which the following are noted:

Isolated crystals,

Plagioclase (bytownite), augite ($c \wedge Z = 45°$), hypersthene, hornblende, and quartz.

Rock-fragments,

Pumiceous two-pyroxene-andesite with phenocrysts of plagioclase ($Ab_{23} An_{77}$) augite ($n_{1D} = 1{\cdot}6940$), and hypersthene. Scoriaceous pyroxene-andesite. Microgranular quartz-rock. Pumice glass.

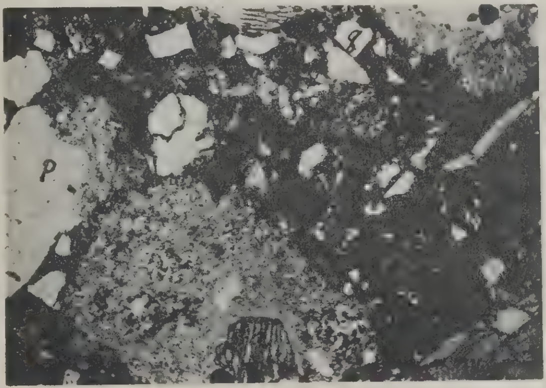

Fig. 5. Microphotograph of tufaceous sandstone. ×28. p—bytownite, q—quartz, ho—hornblende, a—augite, hy—hypersthene.

IV. ***Pyroxene-andesite*** (Takatoriyama bed.) (Fig. 6.)

This rock occurs as blocks in the Takatoriyama gravel-bed which passes laterally into agglomerate and downwards into lava of the pyroxene-

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38) 鴫立澤 39) 照ヶ崎

andesite. It is exposed only in the southern part of the district at Takatoriyama and southwards. At Takatoriyama it rests on siliceous sandstone, the oldest bed (o? in Table I) of the district.

Megascopic Characters.—This rock is dark gray, and is free from phenocrysts except plagioclase, which however is very rarely found.

Microscopic Characters.—Plagioclase occurs as phenocrysts scattered through the groundmass. The plagioclase phenocryst, 0·1–0·3 mm. in diameter, is twinned according to the albite and Carlsbad laws. Very faint zoning of less and more calcic plagioclases is exhibited. . The mineral was identified as bytownite $Ab_{18}An_{82}$ with $n_{1D}=1{\cdot}5710$ and $n_{2D}=1{\cdot}5775$.

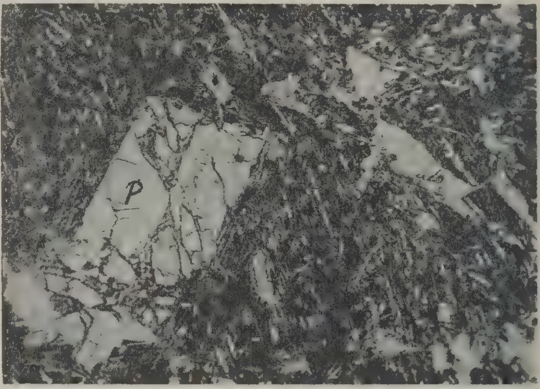

Fig. 6. Microphotograph of pyroxene-andesite. ×56.
p—bytownite.

The groundmass consists of plagioclase laths (0·1–0·3 mm. in length), augite prismoids (0·01 mm. in length), magnetite grains, and a brown glass base. The refractive index of the glass is a little higher than 1.5276.

V. Conglomerate (Nisikoiso bed.)

This rock occurs as a basal gravel-bed, resting unconformably on the Ôiso bed. As far as is visible, this rock exists only in a small area lying to the west of Nisikoiso.

Megascopic Characters.—The rock consists of round blocks or pebbles of various other rocks, loosely cemented with sands and calcareous material containing foraminifera and shell fossils.

Microscopic Characters.—The sandy part of the conglomerate is composed of the following material:

Isolated crystals,
  Plagioclase ($Ab_{45}An_{55}$), augite ($n_{1D}=1{\cdot}6930$–$1{\cdot}6945$), hypersthene and quartz.
Rock-fragments,

Pumiceous hypersthene-andesite with phenocrysts of plagioclase ($Ab_{16}An_{84}$) and hypersthene (n_{1D}=1·7053). Scoriaceous augite-andesite.

VI. Tufaceous shale (Ninomiya bed.) (Fig. 7.)

This rock occupies the greater part of the Ninomiya bed and is distributed in Azumamura[40] adjoining Ninomiya and westwards.

Megascopic Characters.—The rock is light gray, fine-grained to medium-grained, and is compact. A sandy part of this rock consists of plagioclase and pyroxene, together with rock-fragments, angular and round, besides a fine tufaceous matrix.

Microscopic Characters.—The rock is composed of the following material:

Isolated crystals,

Plagioclase ($Ab_{15}An_{85}$) and augite (n_{1D}= 1·6948).

Rock-fragments,

Augite-andesite with phenocrysts of plagioclase ($Ab_{17}An_{83}$) and augite. Scoraceous hypersthene-andesite with phenocrysts of plagioclase ($Ab_{27}An_{73}$) and hypersthene. Brown glass pieces.

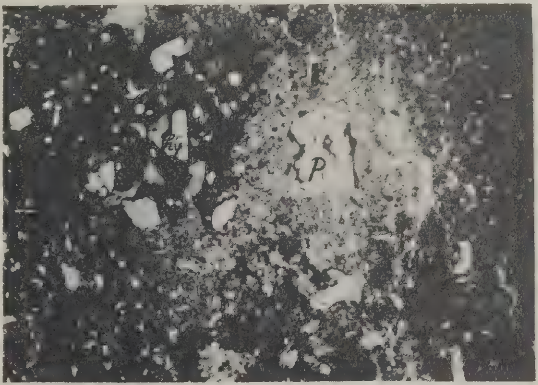

Fig. 7. Microphotograph of tufaceous shale. ×26. p—bytownite. hy—hypersthene in a scoriaceous fragment of hypersthene-andesite.

VII. Dacitic tuff (Tutizawa bed.) (Fig. 8.)

This rock occurs as sandy and clayey beds at Tutizawa, where it is associated with brown coal. The sandy part of the tuff passes laterally into tufaceous clay containing fossils of "*Corbicula nipponensis* Prim." and "*Juglans sieboldiana* Max.[41]" In a little higher horizon than the beds of sandy tuff and tufaceous clay there occurs a finely stratified bed of pumice which is also found abundantly in the lower tuff.

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[40] 吾妻村

[41] Y. Ôtuka, *loc. cit.*, 455–456.

Megascopic Characters.—It is light yellowish gray, fine-grained to coarse-sandy, and is moderately congealed. In its sandy part are found crystals, usually less than 1 mm. in diameter, of plagioclase, hornblende, and pyroxene, together with pumice-fragments up to 2·5 cm. in diameter.

Microscopic Characters.—The rock contains much pumice. The pumice hold a few phenocrysts of plagioclase, hornblende, hypersthene, and augite. The plagioclase phenocryst, 0·4–1·0 mm. in diameter, is euhedral, and is twinned according to the albite and Carlsbad laws. Zonal structure due to the chemical difference is exhibited. The less calcic shell part of the mineral was identified as labradorite ($Ab_{45}An_{55}$), and the more calcic core part as bytownite ($Ab_{25}An_{75}$). The hypersthene, 0·1–0·2 mm. in length, is very weakly pleochroic with its optical plane often normal to the c-axis. Augite and hornblende occur as very minute crystals. The groundmass of the pumice is colorless glass with refractive index $n_D = 1{\cdot}5083$. In addition to the pumice, the tuff contains angular fragments of pyroxene-andesite.

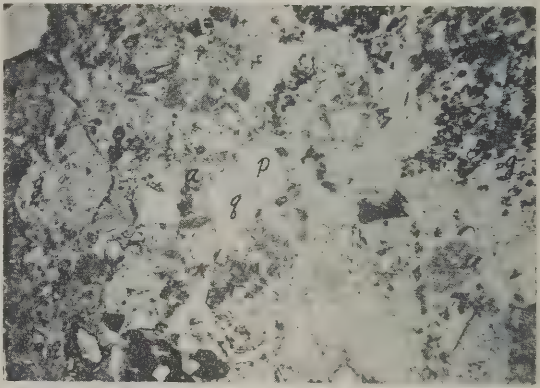

Fig. 8. Microphotograph of dacitic tuff. ×24.
q – quartz, p—labradorite, a – augite, g – pumice.

Isolated crystals contained in the tuff are plagioclase ($Ab_{38}An_{62}$-$Ab_{45}An_{55}$), hornblende ($n_{1D} = 1{\cdot}6617$, $n_{2D} = 1{\cdot}6737$), hypersthene ($n_{1D} = 1{\cdot}7045$), augite ($n_{1D} = 1{\cdot}6930$), and quartz (bipyramidal form).

VIII. *Olivine-augite-andesite* (Kuroiwa bed.) (Fig. 9.)

This rock occurs in the vicinity of Kuroiwa as the main constituent of the Kuroiwa gravel-bed.

Megascopic Characters.—The rock is dark gray, and is very porous. It is porphyritic with phenocrysts of plagioclase, pyroxene, and olivine.

Microscopic Characters.—The rock is sempatic, percrystalline, and consists of phenocrysts of plagioclase, augite, and olivine, together with a groundmass consisting of plagioclase, augite, magnetite, and a little glass base.

The plagioclase phenocryst is euhedral and is twinned in polysynthetic lamellae according to the albite law. Zonal structure due to the chemical difference is very faintly exhibited. The mineral was identified as anorthite Ab_4An_{96} with $n_{1D}=1{\cdot}5780$. The less calcic shell part is bytownite-anorthite Ab_{10}-An_{90} with $n_{1D}=1{\cdot}5750$.

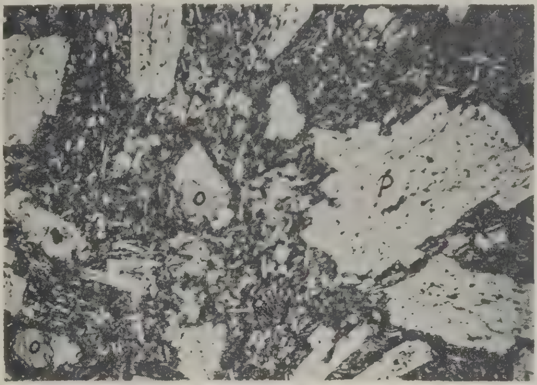

Fig. 9. Microphotograph of olivine-augite-andesite. ×30. p – anorthite, o – olivine.

The olivine has a refractive index $\alpha_D=1{\cdot}6804$. The augite phenocrysts are subordinate in amount.

IX. Two-pyroxene-andesite (Takao bed.) (Fig. 10.)

This rock occurs in the northern half of the Ôiso district as a pumice-bed 10 m. or more in thickness.

Megascopic Characters.—The rock is pumiceous and is white to light gray. It is slightly porphyritic with phenocrysts of plagioclase and pyroxene.

Microscopic Characters.—The rock is dopatic, consisting of a few phenocrysts of plagioclase, augite, and hypersthene, together with an entirely glassy groundmass.

The plagioclase phenocryst, 0·1–0·3 mm. in diameter, is euhedral. Zonal structure due to the chemical difference is absent. The mineral was

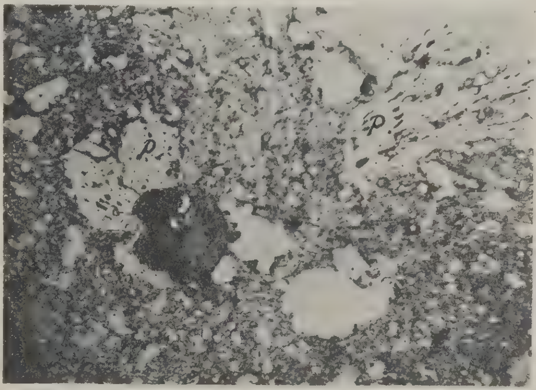

Fig. 10. Microphotograph of pumice (two-pyroxene-andesite). ×38. p – calcic bytownite, hy – hypersthene.

identified as calcic bytownite $Ab_{12}An_{88}$ with $n_{1D}=1{\cdot}5742$. It contains inclusions of brown glass. The augite phenocryst has a refractive index $n_{1D}=1{\cdot}6955$, and the hypersthene $n_{1D}=1{\cdot}6939$.

In addition to the pumice of two-pyroxene-andesite, the Takao bed[42] contains a few-fragments of hypersthene-augite ($n_{1D}=1{\cdot}6928$)-anorthite-andesite and of olivine ($\alpha_D=1{\cdot}6790$)-augite ($n_{1D}=1{\cdot}6966$)-anorthite-andesite.

X. Loam (Loam bed.)

The so-called loam bed of the Ôiso district rests on the Takao bed almost horizontally, and covers unconformably other beds older than the latter. A specimen of the loam collected from the upper horizon of the loam bed at Sinseiko[43] adjoining Hatano[44] was free from any minerals that could be determined megascopically or microscopically. Thin layers of black scoriaceous lapilli are found in some horizons of the loam bed. In the lapilli are seen a few isolated crystals of plagioclase ($Ab_{13}An_{87}$) and augite ($n_{1D}=1.6922$), together with pieces of obsidian ($n_D=1.5078$).

25. 相模國南西地域の堆積岩の岩石學的研究（二）

地震研究所　津屋弘逵

この論文は大磯地塊の地層を構成する岩石の岩石學的研究の結果である。大塚彌之助理學士の研究によれば大磯地塊は新第三紀層及び第四紀層より成る。これらの地層を構成する岩石は主として火山物質を材料とする堆積岩である。大塚理學士の研究されたこの地方の地質層序に從つて各地層を代表する岩石を檢べた結果、新第三紀層以後この地方に少くとも次の四期の火山活動が行はれたものと推定される。

1） 中新期—或はそれ以前・・・・・・・・・石英安山岩の噴出
2） 中新期—鮮新期・・・・・・・・・・・・基性安山岩の噴出
3） 洪積期前期・・・・・・・・・・・・・・石英安山岩及び基性安山岩の噴出
4） 洪積期後期・・・・・・・・・・・・・・最基性安山岩の噴出

現在では以上の四期以上に細分する確かな材料がない。然しこの地方に比較的酸性の火山岩と

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[42] In a little lower horizon than the pumice-bed (Takao bed) there occurs a yellowish gray tuff-bed. The tuff contains abundant crystals of anorthite (Ab_7An_{93}), hypersthene ($n_{1D}=1{\cdot}6892$), augite ($n_{1D}=1{\cdot}6925$), olivine ($\alpha_D=1{\cdot}1743$, $\beta_D=1{\cdot}6905$), and a few fragments of hornblende, together with scoriaceous fragments of olivine-pyroxene-andesite.

[43] 震生湖

[44] 秦野

基性の火山岩とが新第三紀以後交互に噴出してゐることはかゝる堆積岩の研究によつて明かにせられた。この事實は伊豆半島の第三紀及びそれ以後の火山岩の噴出順序にも認められ、伊豆七島の新しい火山島に於ても認められてゐる。

所謂大磯地塊内にはその地層を構成する岩石に含まれてゐる火山物質を供給したと考へられる火山が存在しない。從つて、かゝる火山物質の本源は隣接地方に存在するに相違ない。大磯地塊の西隣には足柄地方及び伊豆地方の火山岩地域があるから、これらの地方の火山岩を研究すれば大磯地塊内の岩石に見られる火山物質の本源を推定し得るかも知れない。本論ではまだそこまで研究を進めてゐないが次の如き二、三の比較を試みた。

1. 大磯地塊で最古（中新期或はそれ以前）の地層と考へられてゐる珪質砂岩は筆者の前報告に記載した江ノ島第三紀層のうち下部三浦層の凝灰質砂岩に岩石學的に可なりよく一致してゐる。著しい相違は前者が石英を多量に含んで珪質なるに反し、後者は中性安山岩片を多量に含んで凝灰質であることである。

2. 大磯地塊の岩石より推定される最古の火山活動を代表する石英安山岩（中新期或はそれ以前）は伊豆地方に發達する數種の石英安山岩に比して斜長石斑晶、有色鑛物斑晶共に結晶作用の早期のものである。伊豆地方に於ても中新期或はその前後の火山活動に屬する石英安山岩は認められるが大磯地塊のそれと岩石學的に又層位學的に如何なる關係にあるかは今後の研究に俟たねばならぬ。

3. 大磯地塊の中新層及び鮮新層に多量に含まれてゐる基性安山岩質の火山物質は何れも類似してゐて層序學的細分に從つて區別し得る特徴を示さない。これらは足柄地方に發達する足柄層及び江ノ島の上部三浦層を構成する岩石に含まれてゐる火山物質に類似してゐる。從つて足柄層及び江ノ島の上部三浦層が大磯地塊の中新層及び鮮新層の何の層位に相當するかは岩石學的に確言し得ない。然し、江ノ島の上部三浦層と足柄層とは少くとも岩石學的には略對比され得るから、足柄層が大磯地塊の下部鮮新層に層位學的に對比されるならば江ノ島の上部三浦層も亦後者に對比されても不都合ではない。

4. 大磯地塊の下部洪積層には石英安山岩質の火山物質が含まれてゐる。これは北伊豆の下丹那附近に發達する洪積層中に含まれてゐる石英安山岩質の火山物質に極めてよく類似してゐる。また前者は植物化石、淡水性の貝化石等を含み、後者は植物化石を含む。地層の揉め方も兩者略同程度である。從つて、兩地層は略對比れさ得るものでその堆積時代に石英安山岩の噴出があつたと推定される。大磯地塊ではこの地層の上に最基性の安山岩物質を含む地層が發達してゐるが北伊豆に於ても箱根、熱海附近の新期の最基性安山岩は下丹那の石英安山岩を含む洪積層より新しい。故に一般に伊豆地方の最基性の玄武岩質安山岩は下部洪積層後の噴出で伊豆七島に於ける大島、三宅島等に於ける如く現在まで續いてゐる。

5. 大磯地塊に發達する所謂ローム層は安山岩質スコリアの如き火山物質を含んでゐるが一般に顯微鏡下にても鑑定し得る鑛物少く他の地方の類似層と十分比較し得ない。

26. *Seismometrical Report.*

地震觀測報告

(Earthquake Research Institute, Tôkyô, Japan.)

(January 1—March 31, 1931.)

Introduction.

The object of this new column is to report all earthquakes that have been felt without instrumental aid as registered at stations in the seismic network framed over the Kwantô districts by the Earthquake Research Institute of the Tôkyô Imperial University. In the case of important earthquakes, their seismograms will be reproduced, while, as of possible aid to international co-operation, distant earthquakes will also be reported.

As shown in List I, there are eight permanent seismological stations in the Kwantô district, and these will supply us with the necessary data. Data from such temporary stations as Wakayama and Idu will not be reported.

(1) *Seismological stations in the Kwantô districts.*

List I.

Station	Coordinates		Approximate distance from Tôkyô (Hongô)
	Longitude (E)	Latitude (N)	
Tôkyô (Hongô)	139° 45′ 59″	35° 42′ 40″	0 km.
Kamakura	139° 32′ 39″	35° 18′ 32″	48
Kiyosumi	140° 09′ 02″	35° 09′ 22″	70
Misaki	139° 37′ 05″	35° 09′ 26″	62
Titibu	139° 04′ 54″	35° 58′ 56″	69
Tôgane	140° 21′ 38″	35° 34′ 00″	55
Tukuba	140° 06′ 36″	36° 12′ 39″	64
Mitaka	139° 32′ 32″	35° 40′ 20″	20

(2) *Instruments.*

List II.

(A) Tôkyô (Hongô).

No.	Name or type component	Weight of the bob (kg.)	Magnification or minification	Natural period (sec.)	Damping ratio	Time scale mm./min.	Remarks
1	(E.W.)	2	1/2	10	2·0	50	With oil damper.
	(N.S.)	2	1/2	10	2·0		
	(Vert.)	1	1/2	6	2·0		
2	(E.W.)	2	2	10	2·5	40	With oil damper.
	(N.S.)	2	2	10	2·5		
	(Vert.)	0·45	2	5	2·0		
3	(E.W.)	15	1½	50	1·5		With oil damper.
	(N.S.)	15	1½	50	1·5		
4	(E.W.)	7	50	7	1·3	60	
	(N.S.)	7	50	7	1·3		
5	(E.W.)	7	50	7	1·5	50	With magnetic damper.
	(N.S.)	7	50	7	1·5		
	(Vert.)	7	28	7	1·5		
6	(E.W.)	30	300	12	1·7	100	
7	(N.S.)	30	300	12	1·7	100	
8	(E.W.)	15	15	50	2·0	15	
9	(N.S.)	15	10	50	2·0	25	
10	(N.S.)	30	120	18	2.0	60	
11	Wiechert (E.W.N.S.)	200	120	14	5·0	10	With air damper.
12	Ewing-Gray type						
	(E.W.)	2	3½	5	1·5	600	Record-receiver starts automatically.
	(N.S.)	2	3½	5	1·5		
	(Vert.)	0·8					
13	Tanakadate						
	(E.W.)	1.5	1		1·5	150	Ditto.
	(N.S.)	1.5	1		1·5		
	(Vert.)	1.5	1		1·2		
14	(E.W.)	17	15	60	3·2	27	With magnetic damper.
15	(N.S.)	42	20	60	2·0	25	Ditto.
16	(E.W.)	10	5	210	1·5	50	
17	(N.S.)	15	1½	210	1·2	40	
18	(E.W.)	40	120	25	2·0	25	

(*to be continued.*)

(A) Tôkyô (Hongô). (*continued.*)

No.	Name or type component	Weight of the bob (kg.)	Magnification or minification	Natural period (sec.)	Damping ratio	Time scale mm./min.	Remarks
19	(N.S.)	60	120	20	2·5	25	
20	Wiechert (Vert.)	1300	120	6	5·0	15	With air damper.
21	(Vert.)	10	20	15	1·7	22·5	
22	(Vert.)	45	7½	20	3·0	4·0	With magnetic damper.
23	Galitzin. (E.W.)	13		Pendul. 24 Galva. 24	∞	27	With magnetic damper.
24	Galitzin. (N.S.)	13		Pendul. 24 Galva. 24	∞	27	Ditto.
25	Galtzin (vert.)			Pendul. 13 Galva. 13	∞		
26	Long Pendulum	300	50	6·7		60	
27	Ishimoto Acceleration seismograph (E.W, N.S.)	13		0·15	∞	57	1 mm. deviation of the index end =1 gal ca.
28	Clinograph (E.W.)	8	15	32			
	(N.S.)	8	15	32		0·12	

(B) Kamakura.

No.	Component	Weight of the bob (kg.)	Magnification	Natural period (sec.)	Damping ratio	Time scale mm./min.	Remarks
1	(E.W.)	2	2	10	2·0	40	With oil damper.
	(N.S.)	2	2	10	2·0		
	(Vert.)	0·45	2	5	2·0		
2	(E.W.)	15	10	30	1·2	15	
3	(Vert.)	4	10	10	2·0	25	
4	(E.W.)	7	50	10	1·5	50	
	(N.S.)	7	50	10	1·5		

(C) Kiyosumi.

No.	Component	Weight of the bob (kg.)	Magnification	Natural period (sec.)	Damping ratio	Time scale mm./min.	Remarks
	(E.W.) (N.S.)	7 7	50 50	7 7	1·5 1·5	50	

(D) Misaki.

No.	Component	Weight of the bob (kg.)	Magnification	Natural period (sec.)	Damping ratio	Time scale mm./min.	Remarks
	(E.W.) (N.S.)	12 12	120 120	4 4	1·5 1·5	50	

(E) Titibu.

No.	Component	Weight of the bob (kg.)	Magnification	Natural period (sec.)	Damping ratio	Time scale mm./min.	Remarks
1	(E.W.) (N.S.)	7 7	50 50	7 7	1·3 1·3	60	

(F) Tôgane.

No.	Component	Weight of the bob (kg.)	Magnification	Natural period (sec.)	Damping ratio	Time scale mm./min.	Remarks
1	(E.W.) (N.S.)	7 7	50 50	7 7	1·5 1·5	50	

(G) Tukuba.

No.	Component	Weight of the bob (kg.)	Magnification	Natural period (sec.)	Damping ratio	Time scale mm./min.	Remarks
1	(N.S.)	35	120	21	2·0	25	
2	(E.W.)	35	120	21	2·0	25	

(H) Mitaka.

No.	Component	Weight of the bob (kg.)	Magnification	Natural period (sec.)	Damping ratio	Time scale mm./min.	Remarks
1	(E.W.) (N.S.) (Vert.)	7 7 7	50 50 28	7 7 7	1·3 1·3 1·3	60	
2	(E.W.)	40	80	18	2·0	25	
3	(N.S.)	40	80	18	1·9	25	

(3) *Sensible earthquakes in Tôkyô for the period January 1—March 31, 1931.*

List III.

Time = Central standard time of Japan (Civil mean time of the meridian 135° E).

Notation:

prel. tr. = Preliminary tremors.
N.S. = North-south component.
E.W. = East-west component.
2A = Range of motion.
T = Period of earthquake motion.
λ = Longitude.
φ = Latitude.
D = Depth.

Intensity: I (slight), II (rather weak), III (weak), IV (rather strong), V (strong), VI (violent).

No.	Station	Date	Time of occurrence	Duration		Maximum motion				Epicentre		D	Intensity
				Prel. tr.	Total	N.S.		E.W.		λ (E)	φ (N)		
						2A	T	2A	T				
			h m s	s	m	μ	s	μ	s	°	°	km.	
1	Tôkyô	Jan. 5	17 14 59·3	15·0	2	32	(0·3)	34	(0·3)	139·6	35·00	90	I
	Kamakura			11·6	2·7	28	(0·3)	48	(0·3)				
	Misaki			12·0	3	21	(0·5)	22	(0·6)				
	Kiyosumi			13·2	2	4	(0·6)	13	(0·9)				
	Titibu			20·8	2			12	(0·8)				
	Tôgane			15·8	2	8	(0.4)	8	(0·4)				
	Tukuba		15 4·8	12·8	1·5								
	Mitaka		17 15 0·6	14.4	2	28	(0·2)	23	(0·2)				
2	Tôkyô	23	1 59 35·4	31·4	12	56	(0·6)	74	(0·6)	141·81	36·80		I
	Kamakura			37·0	14	30	(0·7)	34	(0·6)				
	Misaki			37·5	10	43	(0·7)	38	(0·6)				
	Kiyosumi			31·5	11	12	(0·9)	20	(0·9)				
	Titibu			35·0	6			68	(0·8)				
	Tôgane			24·8	10	26	(0·8)	16	(0·7)				
	Tukuba		1 59 22·1	21·5	5								II
	Mitaka		1 59 39·0	32·5	10	116	(2·4)	86	(2·1)				
3	Tôkyô	30	10 40 29·5	6·9	4	294	(0·4)	340	(0·4)	139·90	36·06	40	II
	Kamakura			13·2	3	10	(0·5)	8	(0·5)				
	Misaki			13·8	4	37	(0·5)	29	(0·7)				
	Kiyosumi			14·2	5	24	(0·5)	20	(0·6)				
	Titibu			8·4	5	44	(0·2)	22	(0·2)				
	Tôgane			9·1	3	44	(0·3)	46	(0·3)				I
	Tukuba		10 40 25·0	6·2	1·8								III
	Mitaka		10 40 32·2	8·7	3·5	86	(0·3)	128	(0·6)				II

List III. (*continued.*)

No.	Station	Date	Time of occurrence	Duration		Maximum motion				Epicentre		(D)	Intensity
				Prel. Tr.	Total	N.S. 2A	N.S. T	E.W. 2A	E.W. T	λ (E)	φ (N)		
			h m s	s	m	μ	s	μ	s	°	°	km.	
4	Tôkyô	Feb. 4	8 33 55·8	12·7	3	36	(0·4)	28	(0·4)	140·00	35·00	50	I
	Kamakura												
	Misaki			8·1	3	20	(0·6)	28	(0·6)				I
	Kiyosumi												
	Titibu												
	Tôgane			11·6	3	22	(0·6)	10	(0·6)				
	Tukuba												
	Mitaka		8 33 56·8	11·7	2·5	15	(0·6)	27	(0·6)				
5	Tôkyô	4	13 37 32·3	12·2	2·5	44	(0·3)	36	(0·3)	139·91	35·29	90	I
	Kamakura												
	Misaki			9·9	3	17	(0·4)	15	(0·4)				
	Kiyosumi		13 37 21·0	11·8	2 5	8	(0·3)	6	(0·2)				
	Titibu			15·4	1	4	(0·3)	4	(0·3)				
	Tôgane			12·1	2	10	(0·3)	10	(0·3)				
	Tukuba												
	Mitaka		13 37 33·0	11·5	2	14	(0·3)	26	(0·3)				
6	Tôkyô	9	23 45 15·0	20·9	3	32	(0·3)	28	(0·3)	139·46	35·27	143	I
	Kamakura			19·3	3	20	(0·6)	30	(0·6)				
	Misaki			19·6	3	29	(1·7)	42	(0·6)				
	Kiyosumi			21·3	3	12	(1·2)	12	(1·2)				
	Titibu			22·3	3	16	(0·9)	12	(0·7)				
	Tôgane			22·5	3	22	(0·8)	20	(0·8)				
	Tukuba		23 45 16·6	25·4	1·6								
	Mitaka		23 45 14·9	20·2	3	32	(0·3)	38	(0·3)				
7	Tôkyô	20	6 42 33·4	5·0	1·5	66	(0·3)	90	(0·3)	139·73	35·79	40	
	Kamakura			8·0	1·5	11	(0·4)	8	(0·4)				
	Misaki			10·0	2	15	(0·8)						
	Kiyosumi			12·0	1·5	6	(0·8)	6	(0·8)				
	Titibu												
	Tôgane			9·6	2	30	(0·5)	25	(0·7)				
	Tukuba		6 42 35·9	8·6	1								
	Mitaka		6 42 33·7	4·8	1	50	(0·3)	62	(0·3)				
8	Tôkyô	20	14 35 34·0	99·7	90	3200	(5·8)	2500	(6·8)	137·60	43·40		I
	Kamakura			103·0	60	900	(4·8)	1100	(3·9)				
	Misaki			110·4	40	360	(1·4)	290	(1·4)				
	Kiyosumi		14 35 39·9	108·5	60	620	(5·0)						
	Titibu			97·5	30	1360	(7·4)	736	(4·8)				
	Tôgane			102·0									II
	Tukuba		14 35 28·0	93·5	29								I
	Mitaka		14 35 35·5	76·2	70								I
9	Tôkyô	23	20 08 07·3	15·3	7	61	(0·3)	40	(0·3)	140·61	36·30	50	
	Kamakura			20·7	7	32	(0·4)	48	(0·4)				
	Misaki			24·2	7	40	(0·6)	30	(0·6)				
	Kiyosumi			19·5	7	64	(3·3)	80	(2·6)				
	Titibu												
	Tôgane			14·9	6	40	(1·8)	46	(1·8)				
	Tukuba		20 07 55·5	9·6	3·5								
	Mitaka		20 08 09·0	17·5	6	48	(2·1)	28	(0·3)				

List III. (*continued.*)

No.	Station	Date	Time of occurrence	Duration		Maximum motion				Epicentre		D	Intensity
				Prel. Tr.	Total	N.S.		E.W.		λ (E)	φ (N)		
						2A	T	2A	T				
			h m s	s	m	μ	s	μ	s	°	°	km.	
10	Tôkyô	Mar. 4	5 39 56·3	25·6	7	70	(0·6)	46	(0·6)				I
	Kamakura			29·0	9	70	(0·5)	62	(0·7)				
	Misaki			31·0	7	57	(0·6)	54	(0·6)				
	Kiyosumi		5 39 59·2	28·3	8	10	(1.2)	20	(1·2)				
	Titibu			27·3	7	24	(0·6)	46	(0·8)				
	Tôgane			24·0	5	100	(1·9)	120	(1·9)				
	Tukuba		5 39 30·2	20·4	6								II
	Mitaka		5 39 59·2	25·0	6	86	(1·0)	54	(0·5)				
11	Tôkyô	7	1 13 37·2	14·8	20	160	(0·5)	104	(0·5)	138·8	35·0		I
	Kamakura			11·7	20	370	(1·2)	140	(1·1)				
	Misaki			11·6	9	164	(0·5)	117	(0·5)				
	Kiyosumi			16·4	15	90	(3·5)	180	(3·5)				
	Titibu			12·2	5	86	(1·2)	11	(1·2)				
	Tôgane			22·3	15	44	(0·8)	26	(0·7)				
	Tukuba		1 13 44·5	20·2	7								
	Mitaka												
12	Tôkyô	7	1 53 49·7	15·4	15	620	(1·0)	310	(1·0)	138·9	35·0		II
	Kamakura			10·2	10	526	(1·1)	414	(1·5)				
	Misaki			10·1	10	455	(0·6)	262	(0·6)				
	Kiyosumi			16·2	10	170	(3·3)	192	(3·3)				
	Titibu			12·6	7	200	(1·0)	290	(1·1)				
	Tôgane			20·1	15	100	(1·0)	120	(1·1)				I
	Tukuba		1 53 54·5	20·0	9								II
	Mitaka		1 53 46·5	11·6	15	950	(1·7)	645	(1·6)				
13	Tôkyô	9	12 50 06·2	82·0	60	5600	(4·0)	8300	(4·7)	142·70	40·75		
	Kamakura			65·5	30	4250	(2·5)	3500	(2·6)				
	Misaki			75·5						(Off the coast of Hatinoye)			
	Kiyosumi		12 50 16·8	82·0									
	Titibu			72·0									
	Tôgane			86·6						(See Fig. 1)			I
	Tukuba		12 49 52·8	65·0	56								I
	Mitaka		12 50 05·8	77·5									I
14	Tôkyô	10	3 41 01·7	9·1	6	164	(0·3)	434	(0·3)	139·23	35·74	45	II
	Kamakura			9·4	6	65	(0·5)	62	(0·5)				
	Misaki			10·6	3	—	—	42	(0·6)				
	Kiyosumi			15·5	6	20	(0·8)	48	(0·9)				
	Titibu			7·4	4	100	(0·4)	108	(0·4)				
	Tôgane												
	Tukuba		3 41 04·8	10·8	2.3								
	Mitaka		3 41 01·3	8·8	4	248	(0·4)	326	(0·7)				II
15	Tôkyô	12	14 06 21·1	13·2	4	80	(0·7)	60	(0·7)	140·30	36·07	80	
	Kamakura												
	Misaki			17·6	3	58	(0·6)	46	(0·6)				
	Kiyosumi		14 06 21·8	16·9	2	4	(0·6)	10	(0·6)				
	Titibu			15·9	3	34	(0·4)	28	(0·5)				
	Tôgane			13·6	2			28	(0·9)				
	Tukuba		14 06 14·7	9·6	2								I
	Mitaka		14 06 22·2	14·1	2·5	62	(0·3)	50	(0·3)				

List III. (*concluded.*)

No.	Station	Date	Time of occurrence	Duration		Maximum motion				Epicentre		D	Intensity
				Prel. Tr.	Total	N.S.		E.W.		λ (E)	φ (N)		
						2A	T	2A	T				
			h m s	s	ffi	μ	s	μ	s	°	°	km.	
16	Tôkyô	Mar. 23	17 28 41·8	7·5	4	52	(0·4)	61	(0·4)	140·2	36·0	30	
	Kamakura			13·4	3	20	(0·9)	20	(0·9)				
	Misaki			13·9	3	18	(0·7)	13	(0·6)				
	Kiyosumi			13·4	4	6	(0·6)	6	(0·6)				
	Titibu			10·4	3	24	(0·3)	20	(0·2)				
	Tôgane			9·0	3	15	(0·8)	26	(0·8)				
	Tukuba		17 28 39·1	5·7	1.7								
	Mitaka		17 28 43·1	9·3	3	15	(0·4)	46	(0·8)				
17	Tôkyô	23	20 24 43·7	6·9	3	24	(0·5)	30	(0·5)	139·83	36·05	20	I
	Kamakura			11·7	3	14	(0·6)	8	(0·6)				
	Misaki			15·3	3	5	(0·5)	3	(0·5)				
	Kiyosumi			14·1	1	4	(1·0)	3	(0·6)				
	Titibu			9·4	2	18	(0·2)	16	(0·2)				
	Tôgane			10·2	3	4	(0·4)	6	(0·5)				
	Tukuba		20 24 35·8	6·2	1.4								
	Mitaka		20 24 39·6	8·8	2·5	10	(0·4)	10	(0·7)				
18	Tôkyô	25	1 29 01·1	3·6	1	36	(0·4)	36	(0·4)				
	Kamakura			6·3	1.2	12	(0·3)	12	(0·3)				
	Misaki			8·1	1	10	(0·6)	10	(1·2)				
	Kiyosumi												
	Titibu												
	Tôgane												
	Tukuba												
	Mitaka		1 29 01·3	5·0	1	36	(0·2)	28	(0·2)				
19	Tôkyô	26	15 30 36·8	11·2	4	64	(0·3)	106	(0·3)	139·09	36.19	15	I
	Kamakura			14·4	3	32	(0·5)	48	(0·5)				
	Misaki			16·9	4	19	(0·9)	13	(0·9)				
	Kiyosumi			20·2	3	4	(0·6)	6	(0·5)				
	Titibu			3·8	3	112	(0·5)	140	(0·5)				
	Tôgane			18·1	2	20	(0·7)	25	(0·7)				
	Tukuba												
	Mitaka		15 30 33·1	11·1	3·5	40	(0·2)	32	(0·2)				
20	Tôkyô	27	5 25 35·9	9·3	4	81	(0·3)	96	(0·3)	140·36	35·34	30	II
	Kamakura			10·4	5	90	(0·6)	145	(0·6)				
	Misaki			9·7	5	57	(0·5)	71	(0·5)				
	Kiyosumi		5 25 31·1	4·9	4	420	(0·5)	448	(0·5)				II
	Titibu			18·0	4	30	(1·3)	20	(0·9)				
	Tôgane			5·0	3	650	(0·2)	550	(0·2)				III
	Tukuba		5 25 37·5	12·0	1.7								
	Mitaka		5 25 40·0	13·5	3·5	166	(0·5)	72	(0·5)				
21	Tôkyô	29	20 14 25·9	6·2	2.5	40	(0·5)	36	(0·5)	139·49	35·54	32	I
	Kamakura			5·7	2	40	(0·4)	24	(0·4)				
	Misaki			7·3	2	22	(0·7)	19	(0·7)				
	Kiyosumi			11·4	3	4	(0·6)						
	Titibu			9·5	2.5	2	(0·5)	4	(0·7)				
	Tôgane			11·5	3	12	(0·5)	8	(0·9)				
	Tukuba		20 14 36·4	10·1	1								
	Mitaka		20 14 25·1	3·8	2	84	(0·5)	105	(0·3)				I

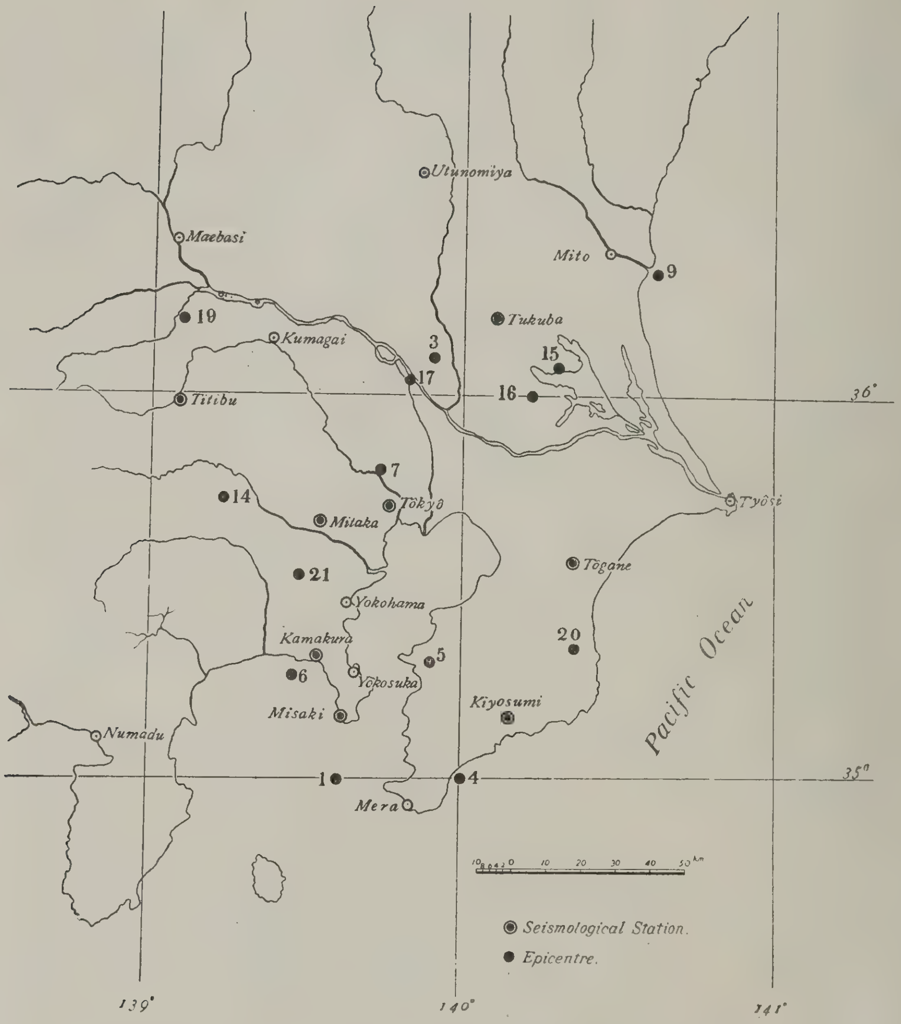

Fig. 2. Distribution of the epicentres of the sensible earthquakes that originated within 160 km. from Tôkyô for the period January 1-March 31, 1931. (Figures attached to each epicentre correspond to earthquake number in List III.)

(4) *Important distant earthquakes as observed in Tôkyô (Hongô).*

List IV.

Notation: EW = East-west component.
+ = towards east.
− = towards west.
NS = North-south component.
+ = towards north.
− = towards south.
G.M.T. = Greenwich mean time.

Date	Phase	Time of occurrence. (G. M. T.)			Amplitude (2A)	Period	Probable epicentre and remarks
		h	m	s	μ	sec.	
Jan 15	P	2	05	22·2			Mexico.
	S	2	16	52·2			
	L	2	34	33·7			
	M(EW)	2	45	01·5	+ 400	25·2	
	M(NS)	2	35	22·2	− 550	23·3	
15	P	21	02	32·8			
	S	21	08	28·5			
	M(EW)	21	10	43·3	− 343	10·7	
	M(NS)	21	11	03·6	+ 363	10·6	
15	P	22	49	23·7			
	S	22	56	16·2			
	L	23	00	13·7			
	M(EW)	23	01	57·6	− 100	23·0	
	M(NS)	23	01	56·2	+ 225	25·0	
27	P	20	16	21·0			
	S	20	23	10·7			
	L	20	28	19·6			
	M(EW)	20	32	02·4	+1170	12·0	
	M(NS)	20	31	27·1	+1300	13·0	
28	P	21	29	24·9			
	S	21	33	57·1			
	L	21	35	21·4			
	M(EW)	21	35	36·2	−3000	25·0	
	M(NS)	21	36	46·2	+2167	27·0	
Feb. 2	P	22	59	09·6			New Zealand, Hawkes Bay.
	S	23	09	20·2			
	L	23	21	37·0			
	M(NS)	23	26	10·0	+1300	43·0	(See Fig. 3, 4)
	M(EW)	23	26	24·0	−1000	37·0	
	M(Vert.)	23	26	29·0	70	32·0	
	M(EW. max.)	23	32	0 (approx.)	2500	21·0	
	M(NS. max.)	23	28	30 (approx.)	1800	27·0	
	M(Vert. max.)	23	29	0 (approx.)	250	26·0	

(*to be continued.*)

List IV. (*concluded.*)

Date	Phase	Time of occurce (G. M. T.)	Amplitude (2A)	Period	Probable epicentre and remarks
10	P	6 44 23·0			
	S	6 51 56·0			
	L(?)	7 05 28·0			
	M(?)	7 08 38·0			
Mar. 19	P	6 30 19·8			
	S	6 35 08·8			
	L	6 37 00			
28	P	12 46 41·0			
	S	12 53 08·0			
	L(EW)	12 57 46·0	2100	58·0	
	L(NS)	12 57 46·0	300	59·0	
	M(EW)	13 00 00	600	63·0	
	M(NS)	13 00 00	1400	60·0	

(5) *Preliminary notes on the strong earthquake of June 17, 1931.*

After the previous report had already been written Tôkyô was strongly shaken by an earthquake in the evening of June 17. This earthquake caused no serious damage. In some parts of Tôkyô, however, electric lights went out owing to breakage of wires on account of shock. It is reported that in Itabasi, a suburb northwest of Tôkyô, a poultry-yard was burned down by fire through overturning of a petroleum lamp. It seemed that the shock was especially strong at the west or northwest suburb of Tokyo. In Yokohama the intensity was somewhat lighter than at Tôkyô, but all the electric lights and all street cars were put out of service for about ten minutes following the shock. Duration of the preliminary tremors at Hongô was 6,8 seconds, the beginning of which was felt strongly as an up-and-down motion. Duration of the sensible shocks at Tôkyô was about 40 seconds.

Times of occurrence of this earthquake at Hongô, Tukuba, Mitaka, Kamakura and Kiyosumi were as follows: These stations are supplied with wireless signals.

Station	Time of occurrence		
Tôkyô	21^{h}	09^{m}	$50{\cdot}3^{s}$
Mitaka	21	09	49.0
Tukuba	21	09	54·3
Kamakura	21	09	52·5
Kiyosumi	22	09	55·3

Durations of the preliminary tremors and directions of the initial motion.

Station	Duration of preliminary tremors	Direction of initial motion
Tôkyô	6·8 sec.	N 73° W down
Mitaka	6·7 ?	N 32° W down ?
Kamakura	10·3	N 21° W down
Titibu	8·1	N 56° W
Kiyosumi	13·5	N 35° W
Tôgane	12·1	N 66° W
Misaki	—	N 15° W
Tukuba	10·0	S 19° W
Koyama	9·6	E
Tanna	11·5	N 40° E down
Itô	11·6	N 32° E

(See Figs. 7—10.)

Maximum Range and period of the earthquake at Hongô.

All the seismographs having magnifications larger than ten-time were put out of order by the strong shock. The pointers of these seismographs were bent and gave only registers of the preliminary portion. The periods and the maximum ranges of component earthquake motions as registered by the strong motion seismograph (No. 3 in List II) were as follows:

Component	Range	(Period)
N. S.	42·1 mm.	(2·4 sec.)
E. W.	20·2 mm.	(2·4 sec.)
Vert.	8·3 mm.	(2.4 sec.)

(See Figs. 5 and 6)

Intensity (Acceleration) of the earthquake.

According to the Ishimoto acceleration seismograph diagram, (see Fig. 11), maximum accelerations of the horizontal component motions at Tôkyô (Hongô) were as follows:

Component	Max. Acceleration	Direction	Time from beginning of the earthquake.
E. W.	49·5 gal.	towards E.	10·4 sec.
N. S.	45·5 gal.	towards S.	9·5 sec.

Intensity of this earthquake was V (strong) in the intensity scale, or VII in the Rossi-Forel scale.

Probable origin of the earthquake. From the data above given the position of the epicentre and the approximate depth work out as follows:

Epicentre	Depth (approx.)
$\lambda = 139{\cdot}6°$ E $\varphi = 35{\cdot}7°$ N	45 km.

Epicentre is probably a point about 20 km. distant from Hongô in a westerly direction.

(N. Nasu and Ch. Yasuda are responsible for this report.)

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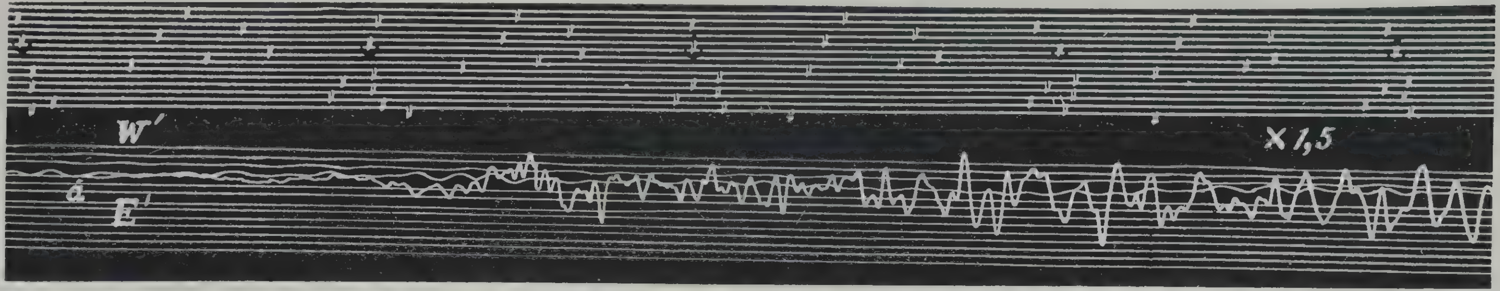
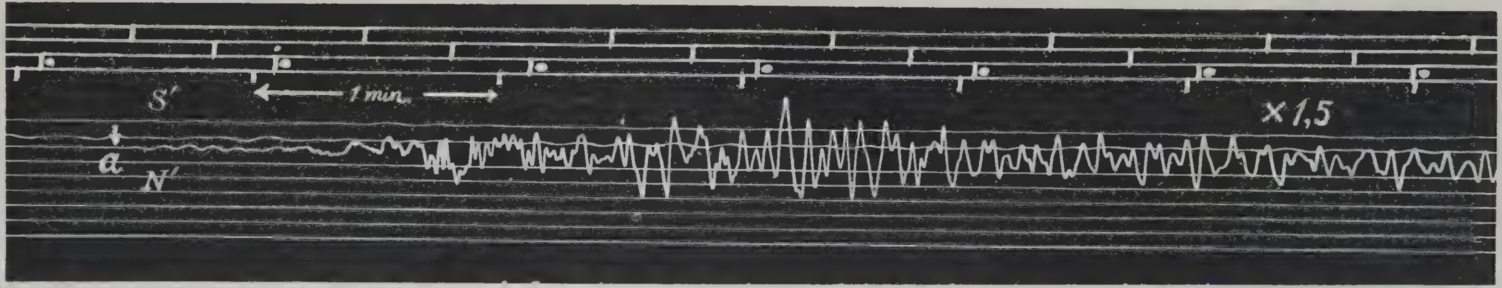
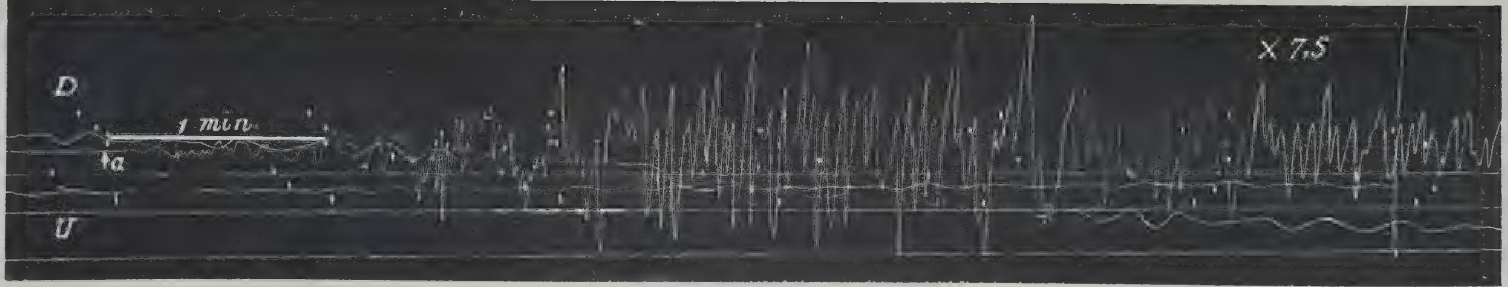
Fig. 1. Tôkyô Observation of the Northeast Japan earthquake of March 9, 1931.
a · · · · · · · · · beginning.



E′ = N 77° E, W′ = S 77° W



N′ = N 13° W, S′ = S 13° E



(*Full size of the original diagrams*)

Instrumental constants: E. W. Component [See No. 3 in List II (A)]. N. S. Component [See No. 3 in List II (A)].
Vertical Component [See No. 22 in List II (A)].

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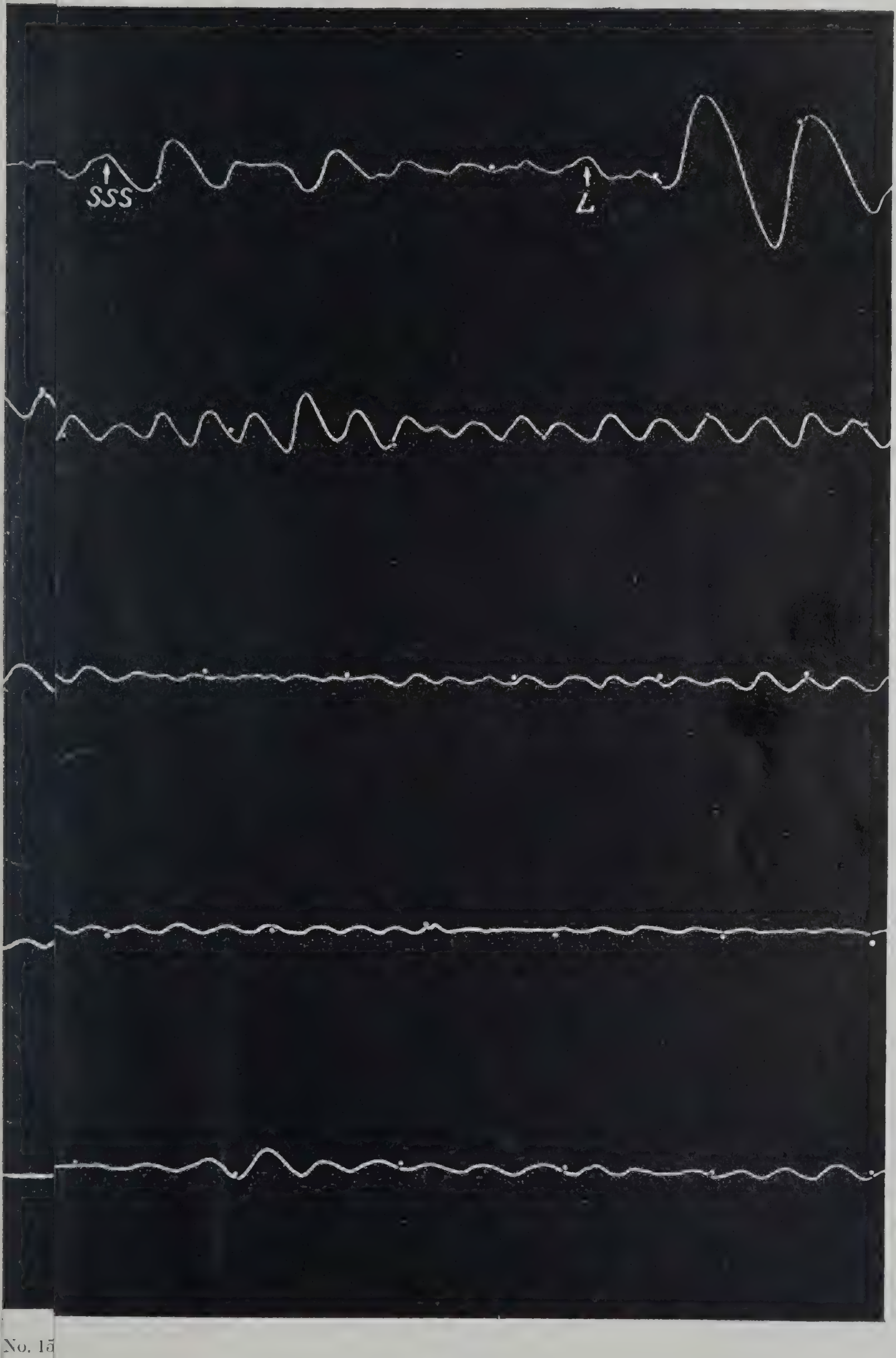

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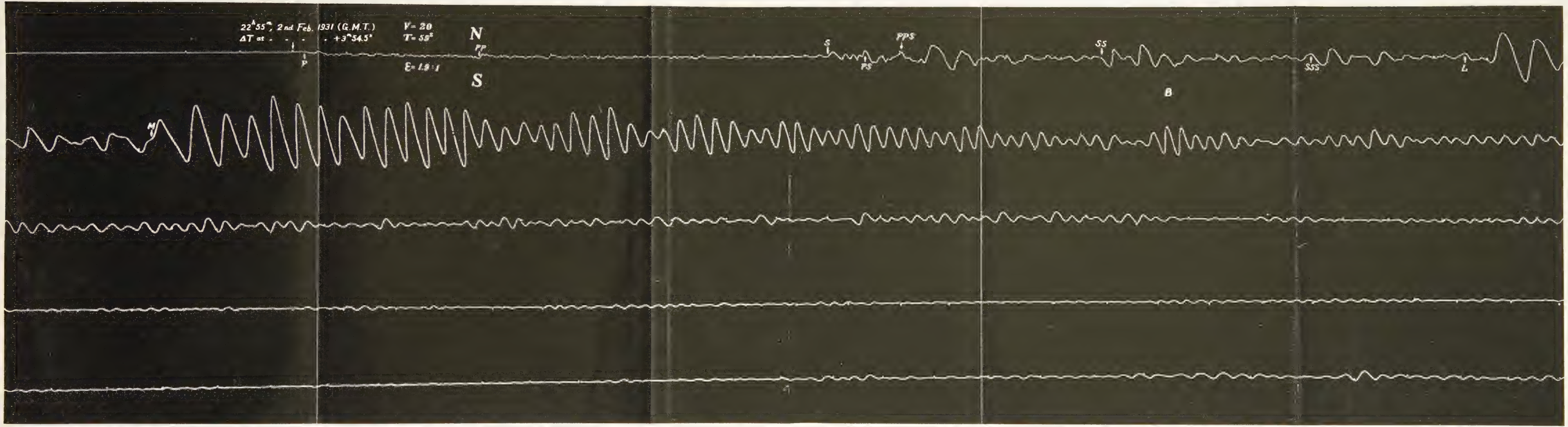
Fig. 3. Tokyō Observation of the New Zealand Earthquake of Feb. 2, 1931



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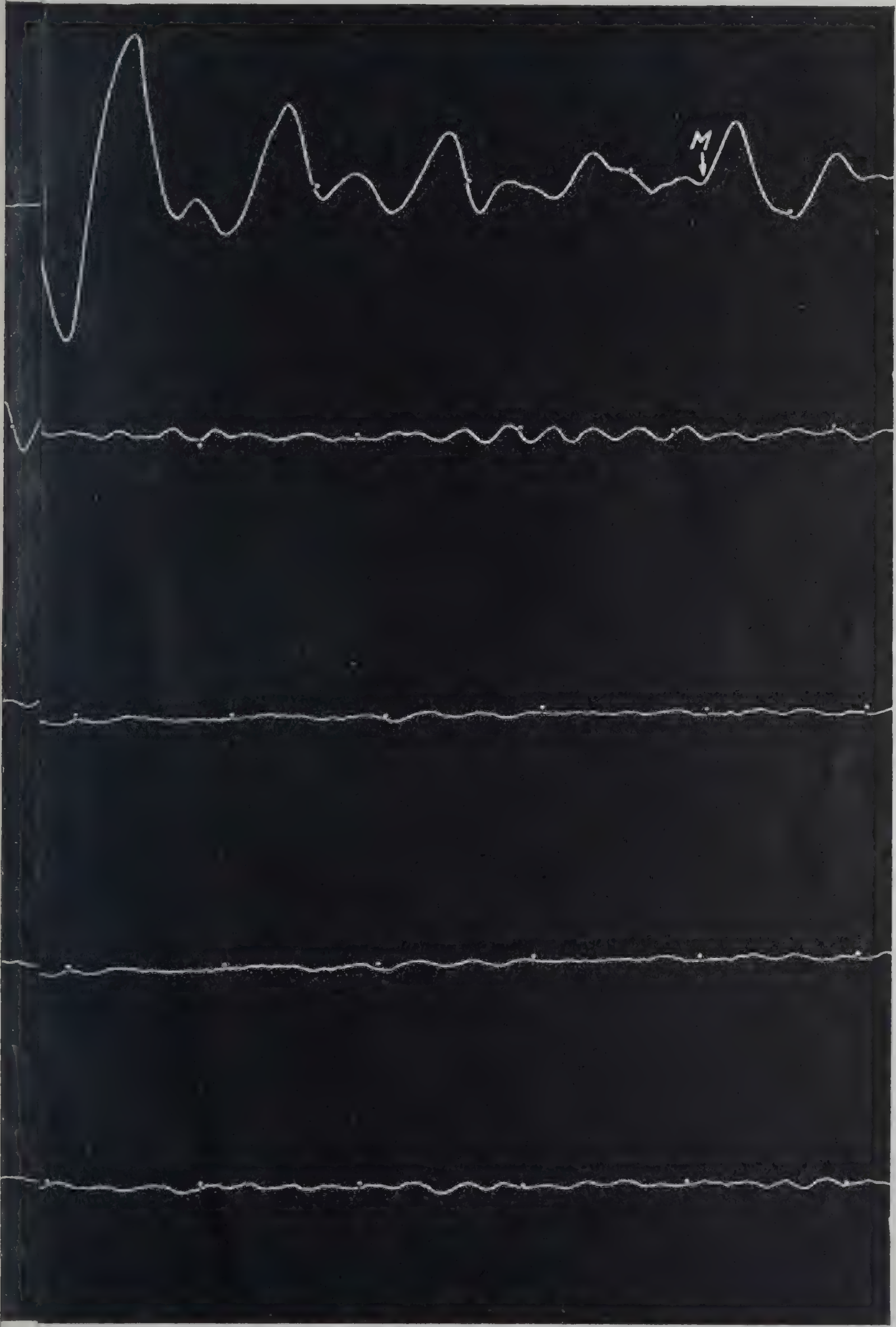

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Fig. 1. Tôkyô Observation of the New Zealand Earthquake of Feb. 2, 1931

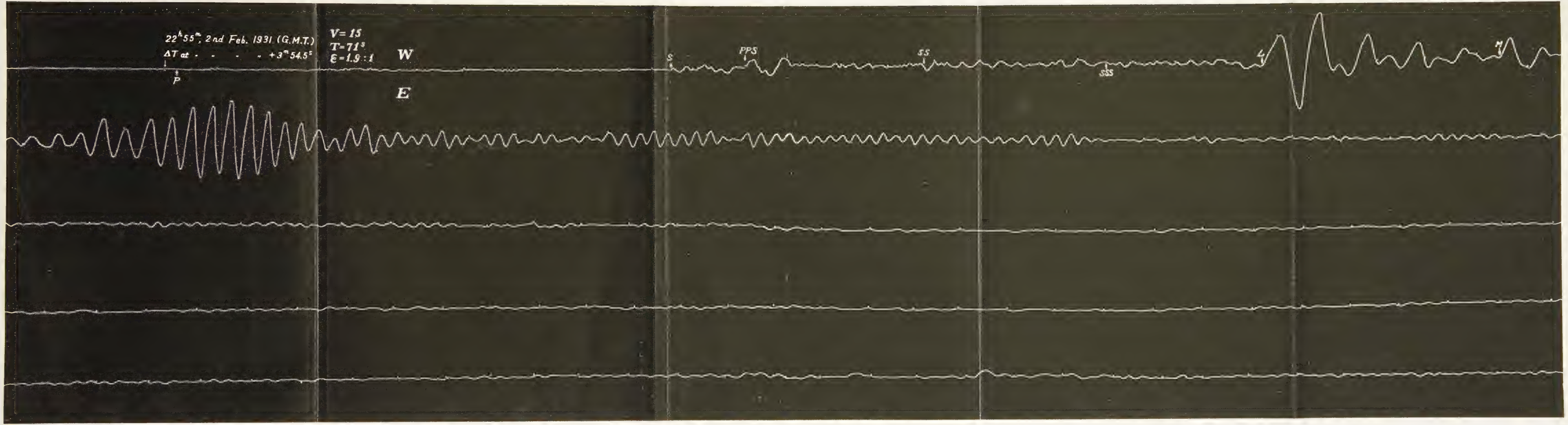

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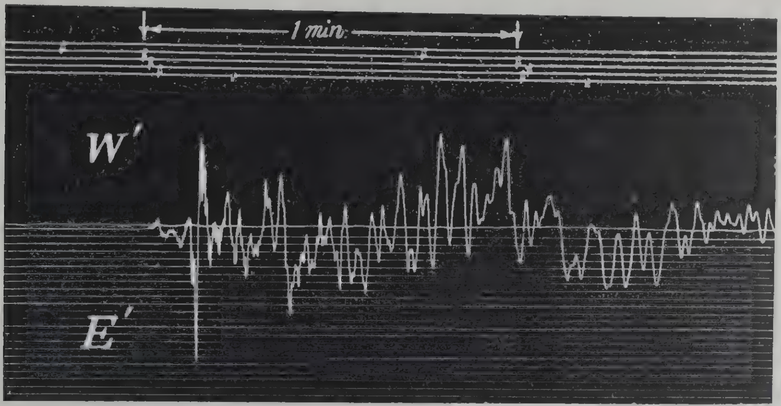
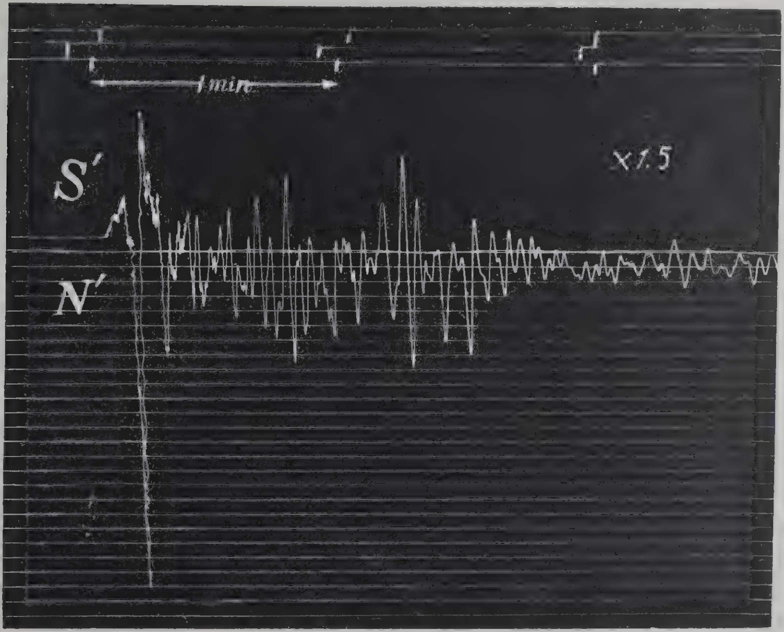
Fig. 5. Tôkyô (Hongô) Observation of the Strong Earthquake of June 17, 1931.
Horizontal Pendulum Strong Motion Seismograph Diagrams.



E′ = N 77° E, W′ = S 77° W (*Full size of the original diagram*)



N′ = 13° W, S′ = S 13° E (*Full size of the original diagram*)

Instrumental constants: E. W. Component [See No. 3 in List II (A)].
N. S. Component [See No. 3 in List II (A)].

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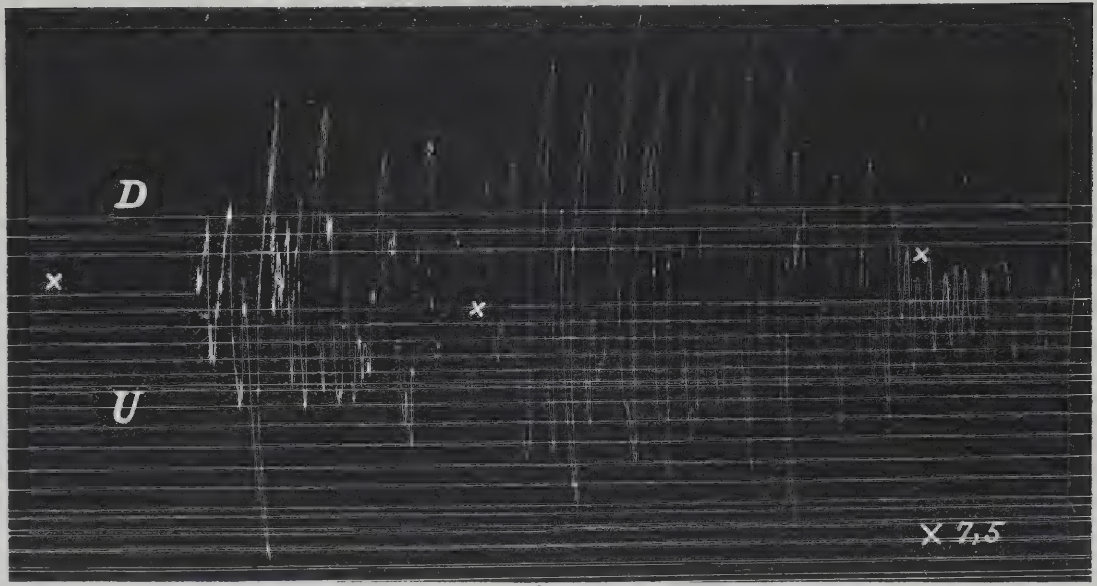
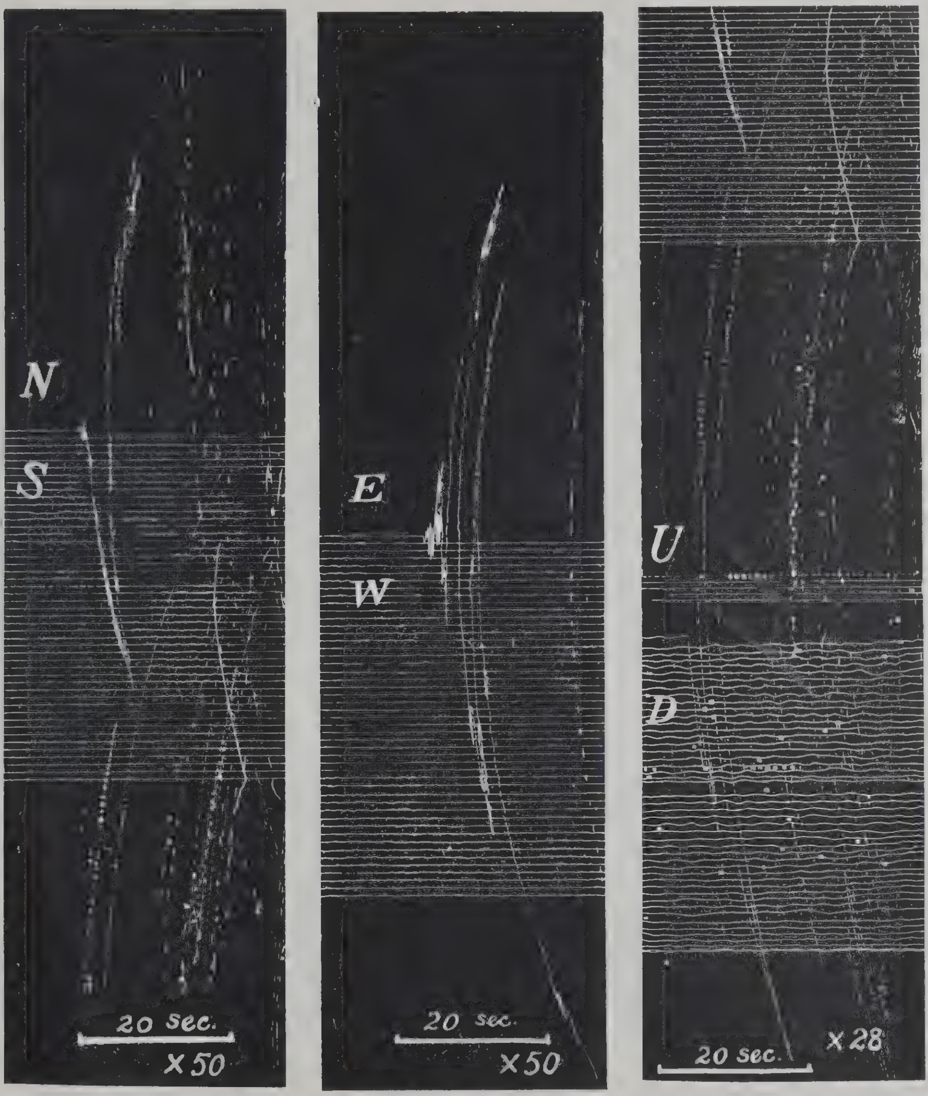
Fig. 6. Tôkyô Observation of the Strong Earthquake of June 17, 1931.
Vertical Seismograph Diagram.



(Full size of the original diagram)

Instrumental constants: [See No. 22 in List II (A)]. In erinal between consecutive two breaks indicated by × equals to 1 minute.

Fig. 7. Tôkyô Observation of the Strong Earthquake of June 17, 1931.
Three Component Motions Seismograph Diagram.



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Instrumental constants: [See No. 5 in List II (A)].

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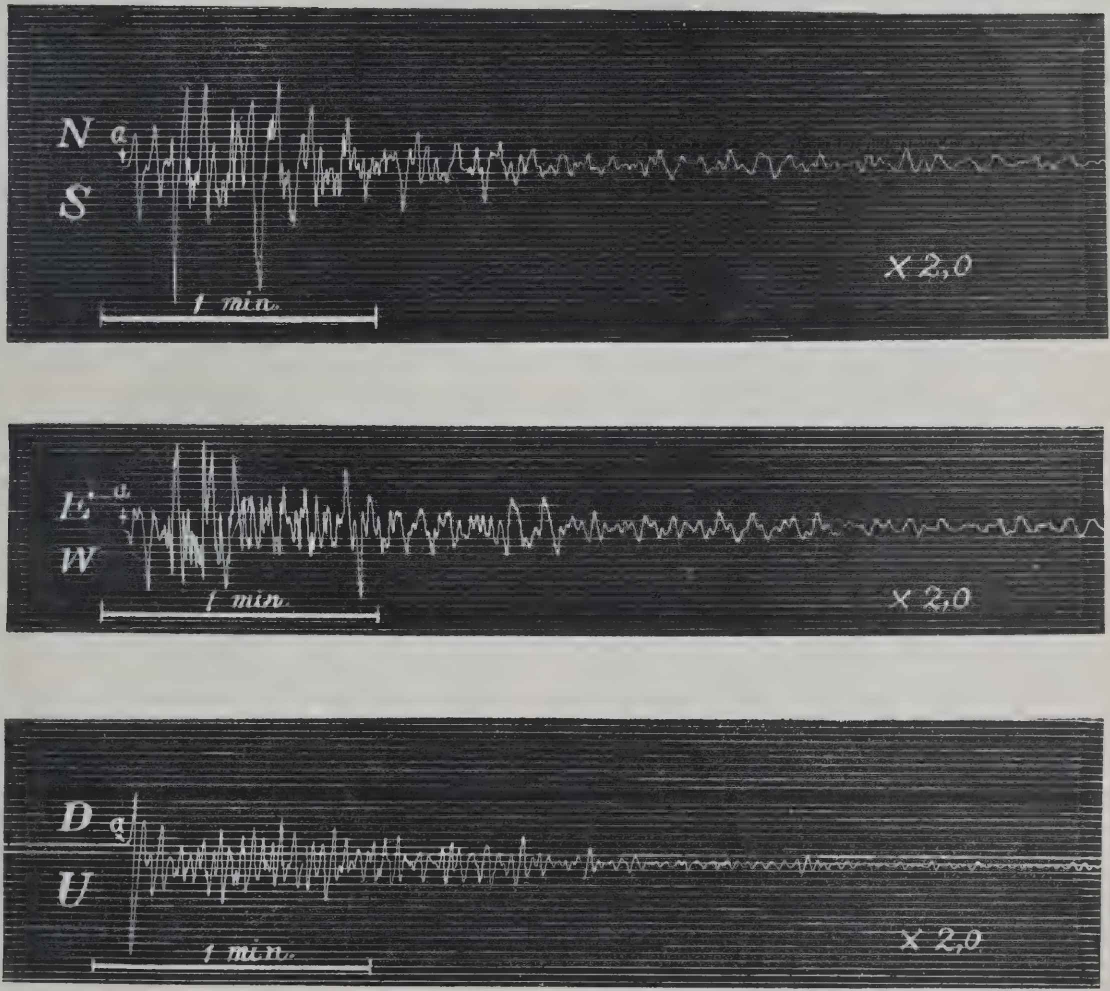
Fig. 8. Kamakura Observation of the Strong Earthquake of June 17, 1931.
Strong Motion Seismograph Diagram.



(*Full size of the original diagram*)

Instrumental constants: [See No. 1 in List II (B)].

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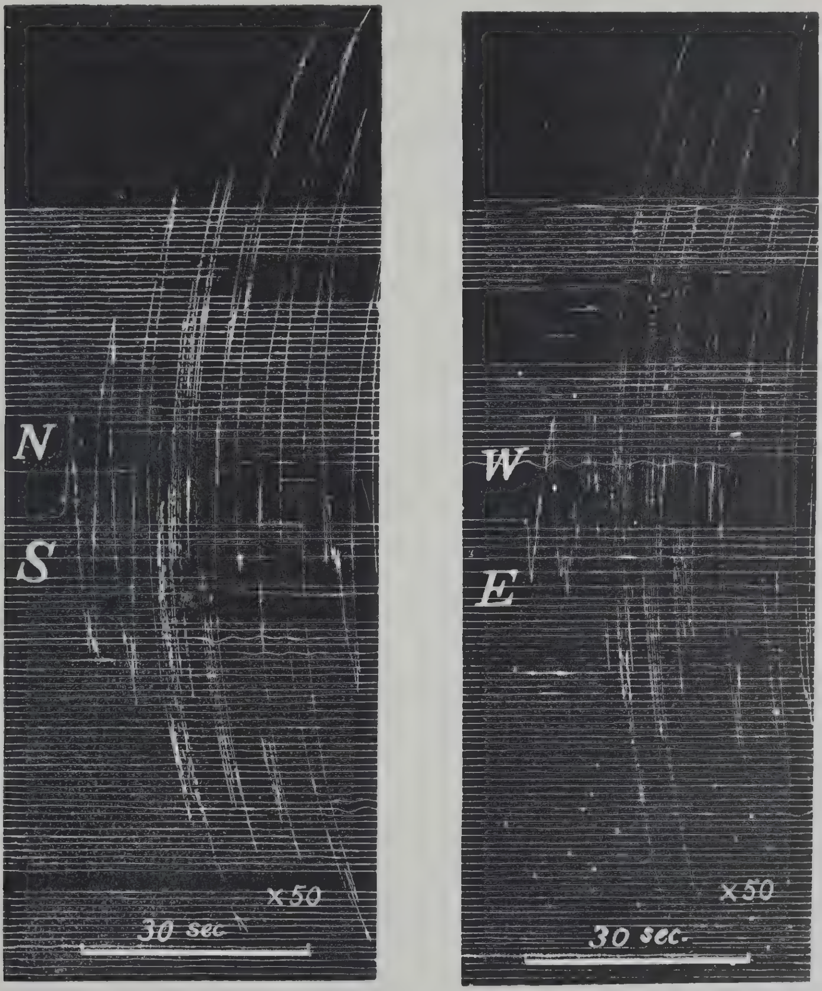
Fig. 9. Itô Observation of the Strong Earthquake of June 17, 1931. Horizontal Motion Seismograph Diagram.



(Full size of the original diagram)

Instrumental constants:

Component	Natural Period	Magnification	Damping Ratio
E.W.	6·5 sec.	50	1·30
N.S.	6·5 sec.	50	1·20

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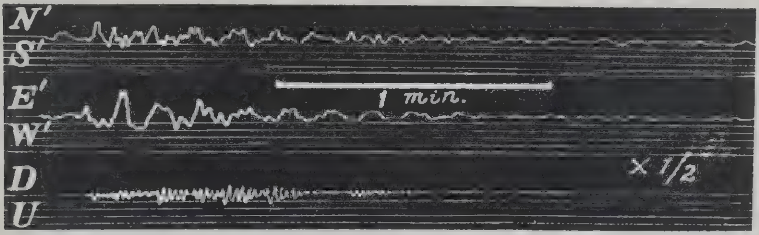
Fig. 10. Tanna Observation of the Strong Earthquake of June 17, 1931.
(A) Strong Motion Seismograph Diagram.
(B) Three Component Motions Tromometer Diagram.

(A)



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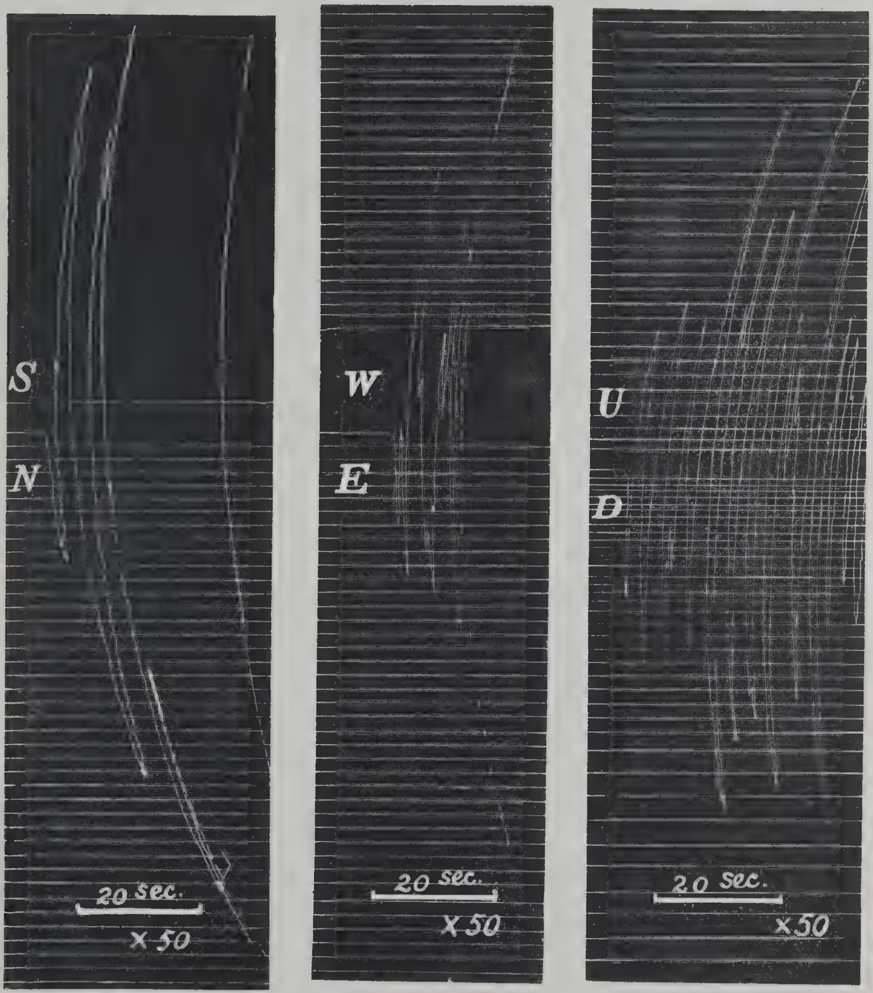
(B)



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Instrumental constants:

(Full size of the original diagram)

		Natural Period	Minification or Magnification	Damping Ratio
Strong motion seismograph	E.W.	10 sec.	1/2	1·30
	N.S.	10	1/2	1·30
	Vert.	4	1/2	1·20
Tromometer	E.W.	5·8	50	1·40
	E.S.	5·4	50	1·58
	Vert.	3·5	50	1·20

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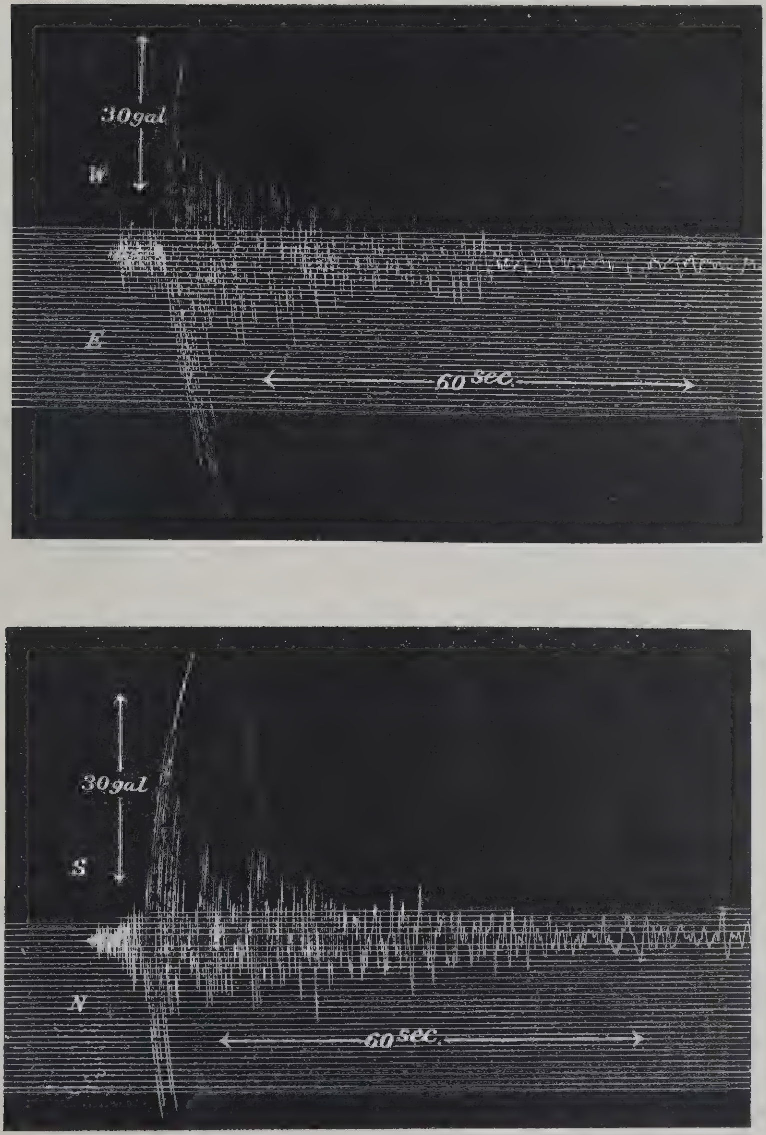
Fig. 11. Tôkyô (Hongô) Observation of the Strong Earthquake of June 17, 1931.
Ishimoto Acceleration Seismograph Diagram.



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1.　日本の鮮新期初期の地殼運動に就て(一)	大塚彌之助
1.　丹那墜道内及丹那盆地の地震動比較(第二報)	那須信治
1.　本邦火山岩の特性に就て	坪井誠太郎
1.　ワレメに就て	寺田寅彦
1.　地震による家屋の振動に就て	末廣恭二

第六十二回談話會　（昭和六年七月七日）

1.　三鷹村東京文天臺に於ける地表傾斜變化觀測	辻光之助
1.　伊豆半島に於ける地殼變動(第二報)	坪井忠二
1.　地震と脈動	井上宇胤
1.　地震加速度の觀測	石本巳四雄
1.　地震群に就て	寺田寅彦
1.　地震動各位相の振副、振動周期、初動に就て	妹澤克惟
1.　內部歪核を有する半無限プラスチコ彈性體の變形	妹澤克惟
1.　地塊運動（第二報）	宮部直巳
1.　武田ビルデング振動驗測結果に就て	福富孝治
1.　大正十五年八月三日羽田强震當時並に其以前に現はれたる地形變動に就て	今村明恒
1.　地震の初動に就て(豫報)	河角廣

○　出　張

1.　昭和六年六月三日地震事項調査の爲靜岡縣下へ出張	宮部直巳
1.　昭和六年六月八日地震調査の爲千葉縣下へ出張を囑託	田山利三郎
1.　昭和六年六月廿二日地質調査の爲神奈川、靜岡縣下へ出張	津屋弘逵
1.　昭和六年六月廿二日傾斜計記錄調査の爲東京府下三鷹村へ出張	石本巳四雄
1.　昭和六年六月廿八日電車々輛振動測定の爲東京府下へ出張	那須信治 佐藤小太郎
1.　昭和六年七月二日地質調査の爲靜岡、神奈川兩縣下へ出張	久野久
1.　昭和六年七月十日地質調査の爲靜岡、神奈川兩縣下へ出張	津屋弘逵
1.　昭和六年七月十四日重力測定に關する調査の爲神奈川縣へ出張	坪井忠二

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Contents.

Papers and Reports.

Page
17. T. Terada, On Luminous Phenomena Accompanying Earthquakes. (in English) 225
18. N. Miyabe, Blocks in the Earth's Crust and their Movements. Part I. (in English) 256
19. C. Tsuboi, On the Results of Repeated Precise Levellings around Idu Peninsula. (in English) 271
20. K. Sezawa and G. Nishimura, Movement of the Ground due to Atmospheric Disturbance in a Sea Region. (in English) 291
21. K. Sezawa, A Kind of Waves transmitted over a Semi-infinite Solid Body of Varying Elasticity. (in English) 310
22. M. Ishimoto, Un sismographe accélérométrique et ses enregistrements. (en Français) 316
23. H. Yabe, Geological Growth of the Tôkyô Bay. (in English) 333
24. Y. Ôtuka, Early Pliocene Crustal Movement in the Outer Zone of Southwest Japan and in the Naumann's Fossa Magna. (in English) 340
25. H. Tsuya, Petrographic Notes on the Sedimentary Rocks of Southwest Sagami Province. (Part II). (in English) 353
26. Seismometrical Report. (in English) 374

Institute Notes.

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F. Omori. The Omachi (Shinano) Earthquakes of 1918. I.

Tokyo. March, 1922.

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Tokyo. March, 1922.

The Omachi (Shinano) Earthquakes of 1918.* I.

By **F. OMORI**, Member of the Imperial Earthquake Investigation Committee.

(*With Plates* I–X.)

1. INTRODUCTION. The two severe earthquakes on Nov. 11, 1918, which shook the town of Omachi and the vicinity, in the province of Shinano, may be classed as small local destructive shocks, and furnish a very interesting material of study in connection with the great Zenkoji catastrophe of 1847 and other former seismic disturbances belonging to the earthquake zones of the Shinano-gawa valley and of the Hime-kawa and Tenryu-gawa valley.

The present author, who was at the time engaged in the field study of the Shirane (Kusatsu) volcano, has been telegraphically requested by Mr. T. Akaboshi, Governor of the Nagano prefecture, to proceed at once to the shaken districts and make investigations of the earthquake shocks still occurring continuously. The author arrived at the scene of disaster on Nov. 14th at noon, and on the strength of the tromometer registers obtained at the Nagano meteorological observatory and a precursory observation of the seismic damage at Omachi and the vicinity, published on the same day a preliminary note, giving an assurance of the non-recurrence of further destructive shocks to the panic stricken people who did not dare to remain in their houses and suffered much from exposure to cold weather.

The author made the field study of the seismic effects during the 7 days till the 20th (Nov.), and again during the 8 days between Nov. 28th and Dec. 5th. A continuous registration of the after-shocks was carried on by means of a portable horizontal pendulum tromometer of 100 times magnification temporarily set up in the compound of the Omachi district office, between Nov. 27th and Dec. 5th, 1918.

The following §§ give a general account of the seismic activity in 1918 of Omachi and vicinity, together with a comparison of the bench mark heights, before and after the earthquakes, along the precise leveling line extending from Matsumoto to Omachi, and thence to Itoigawa on the Japan Sea coast.

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* Translation, with additions, of my report on the Omachi earthquakes published in the Japanese Reports of the Imp. Earthq. Inv. Comm. (Shinsai Yobo Chosakai Hokoku), No. **94**.

2. AFTER SHOCKS AND REPETITION OF GREAT DESTRUCTIVE EARTHQUAKES. A great earthquake is always followed by numerous secondary shakings, which decrease very quickly at first, but which may, according to the magnitude of the initial disturbance, continue for several months or several years, sometimes even for more than 10 years. The after-shocks, whose number may amount to several hundred or several thousand, gradually bring back the disturbed region to equilibrium condition, and are much smaller and weaker than the main earthquake, their principal origins being in the immediate neighbourhood of that of the latter. Now a great destructive earthquake is equivalent to the removal of a long continued excess of stress in the earth's crust of the region concerned. Further, the seismic focus has a depth less than a certain limit, say, 20 ri (=80 km.), while its length may extend over the horizontal distance of more than 100 km. or even 100 miles. Hence it may be assumed that great destructive earthquakes do not happen from one and the same point or local tract. It is, of course, possible that such shocks originate from the same earthquake zone. In such cases, however, the centres would be widely separated from one another. Thus, the great Japan earthquake of Dec. 23rd, 1854 took place off the coast of Tokaido, while the equally great earthquake on the next day, Dec. 24th, took place off the coast of Nankaido at the distance of more than 400 km. to the S.W. along the same seismic zone on the convex, or Pacific, side of the Japan arc. Again, the great Valparaiso and the Aleutian Islands earthquakes on Aug. 16th, 1906, occurred almost simultaneously from the southern and northern parts of the earthquake zone along the Pacific coast of North and South America at a mutual distance of 10,000 miles.

3. AFTER-SHOCKS AND REPETITION OF SMALL LOCAL DESTRUCTIVE EARTHQUAKES. A small destructive earthquake is one whose area of strong motion is limited and which is sufficiently strong to damage ordinary brick chimneys, stone structures, badly built brick houses, and to cause slight cracks of the ground, but which does not attain the magnitude of a great destructive earthquake, namely, one capable of completely destroying a wooden Japanese dwelling house. A small destructive shock as here defined may prove very disastrous in some other places such as Southern Italy, where houses are made of very bad building material.

Local destructive shocks may often occur twice, unlike large ones, from neighbouring places in the course of one day or two. For instance, in Dec. 1892, two strong earthquakes of local nature occurred off the coast of the S.W. part of the province of Noto (Hokrikdo, Japan) respectively on the 9th, at 10. 40 A.M. and on the 11th, at 1. 30 A.M., with the mutual time interval of

Pl. I.

Fig. 1. Map showing the Shinano-gawa Valley and the Hime-kawa and Tenryu-gawa Earthquake Zones.

I......Shinano-gawa Eq. Zone. II......Hime-kawa and Tenryu-gawa Eq. Zone.

A .....Destructive motion area of the Sanjo (Echigo) Eqke. of 1828.

B .....Approximate position of the epicentre of the Sado and Shonai Eqke. of 1833.

C......Destructive motion area of the great Zenkoji Eqke. of 1847.
(The inner area indicates the districts where the seismic damage was specially heavy.)

●......Centres of the Local Destructive Earthquakes :—

1 Omachi-gumi Eqke., 1714.
2 Iiyama Eqke., 1718.
3 Matsushiro Eqke., 1858.
4 Eqke. of 1886.
5 „ 1887.
6 Eqke. of 1890.
7 „ 1897.
8 „ 1899.
9 Shizuoka Eq., 1917.
10 Omachi Eqkes., 1918.

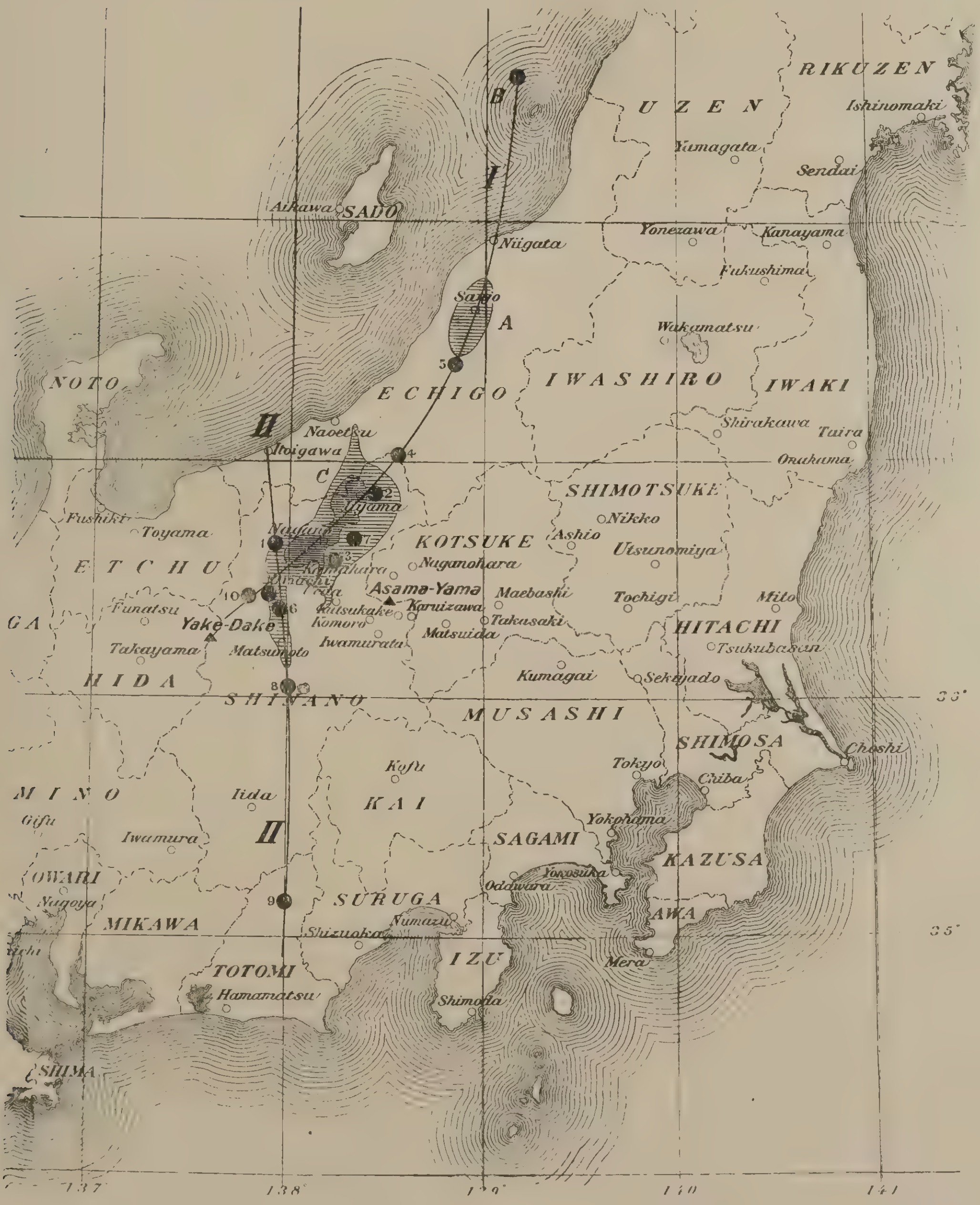
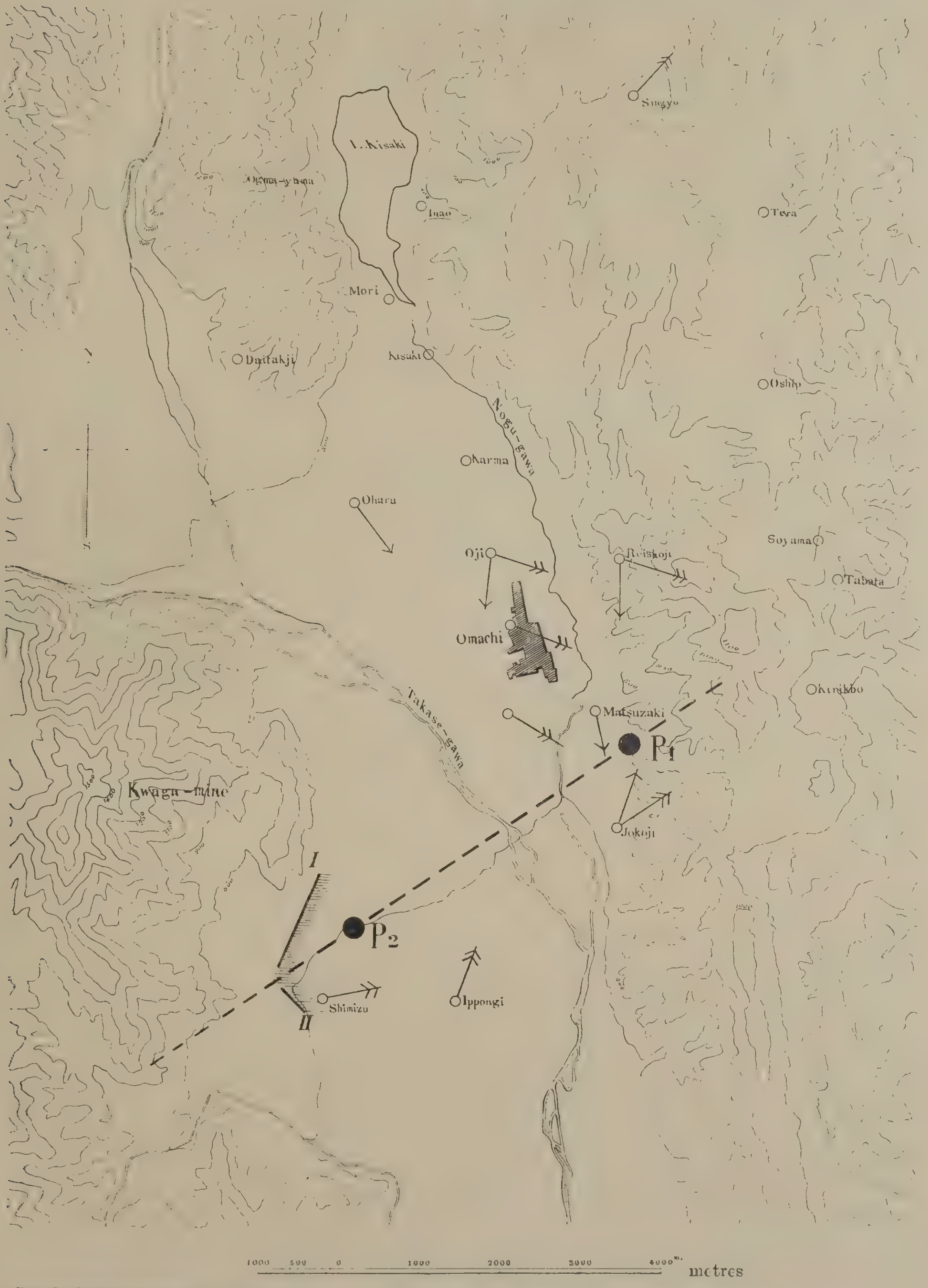


Fig. 2. **Map of the Epicentral District of the Two Destructive Omachi Earthquakes on Nov. 11, 1918.**

P_1P_2......Focal Zone of the 2nd Destructive Shock, forming the S.W. continuation of the Shinano-gawa Earthquake Zone.

P_2......Central Point of the Zone P_1P_2. P_1......Epicentre of the 1st Destructive Shock.



Single-feathered arrow indicates the direction of the strongest-motion of the 1st shock, and the double-feathered that of the 2nd shock.

I, II......Small Dislocation Lines, the shade on the E. side indicating the relative depression of the ground.

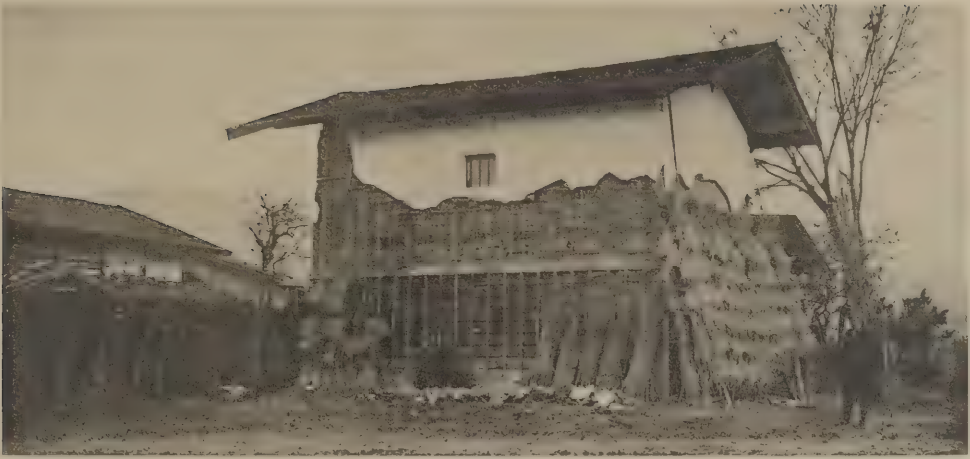


Fig. 3. A *Dozo* (Japanese Ware-house) at Shimizu, Tokiwa-mra, with its mud wall badly shaken down

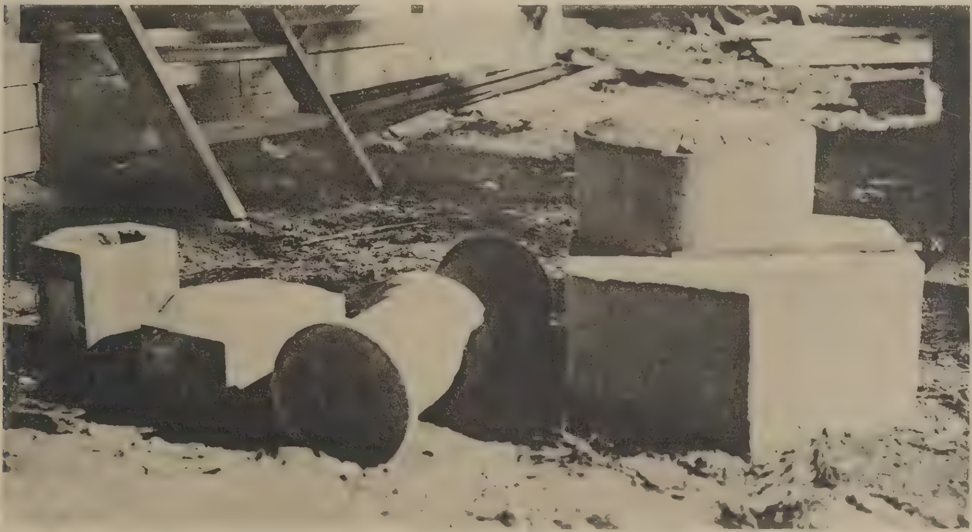


Fig. 4. A Stone-lantern overturned, at Jokoji (常光寺) Temple, Yashiro-mra. (×) .... A foot-scale indicating the amount of the displacement of the pedestal.

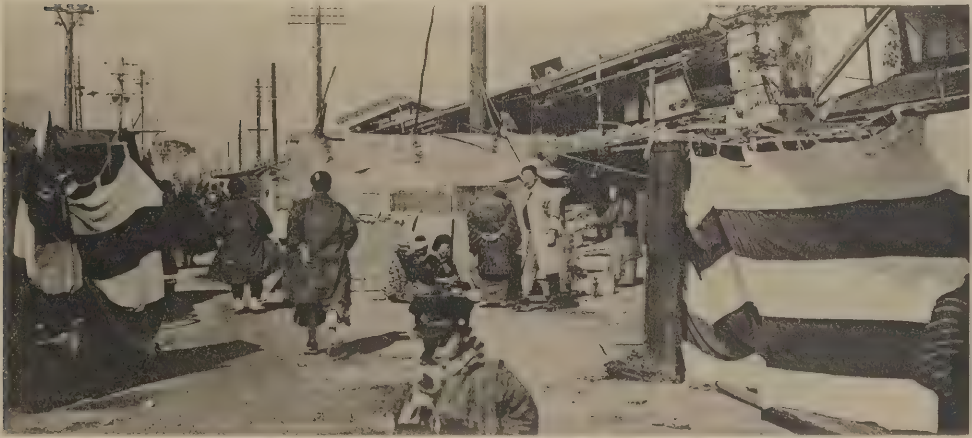


Fig. 5. Street Scene in the Town of Omachi after the Earthquakes.

38.8 hours. Again, in Aug. 1898 the Itoshima district, in the W. part of the province of Chikzen (Kyushu) was shaken by two strong shocks on the 10th, at 9. 57. 31 P.M., and on the 12th, at 8. 35. 34 A.M., with the time interval of 35.6 hours. In each of these cases, the second earthquake was a little stronger than the first, while the occurrence of the after-shocks following the latter was not sufficiently abundant. Thus, the first strong Itoshima earthquake was followed by only 3 after-shocks previous to the occurrence of the second strong earthquake, which was followed by a sufficient number of after-shocks, amounting to 34 in the course of the same day. It is likely that when a local seismic district reaches the limiting state of underground stress accumulation two small destructive earthquakes may take place from within the affected area with a mutual distance of 5 to 10 km.

4. COURSE OF OMACHI SEISMIC ACTIVITY. At the Tokiwa-mura, 6 km. to the S.W. from Omachi, a slight shock was felt on the 10th (Nov.) just after the supper time, another slight one being felt at about 10 o'clock on the same evening. In the vicinity of the Oji temple, at the northern part of the town of Omachi, sounds like those due to avalanches were perceived toward the W.S.W. at about 10 P.M., on the 10th. Similar sounds were also heard on the same day at about 4 P.M. at the village of Krumibara to the N. of Omachi. These might possibly have been the fore-shocks of the two destructive earthquakes on the 11th whose times of occurrence were, according to the tromometer observations at the Tokyo Seismological Institute, respectively 2. 58. 45 A.M. and 4. 03. 40 P.M., with the mutual time interval of 13.1 hours, the 2nd earthquake being much larger than the first. According to the tromometer records at the Nagano Meteorological Observatory, the after-shocks which followed the 1st destructive earthquake were comparatively few in number, probably in indication of the continued unstable condition of the focal district. Thus there resulted the 2nd destructive earthquake, followed by numerous after-shocks, some of which were moderately strong. This may be taken as the result of the removal of the principal underground weak points of the district under consideration, which may be assumed to be free in future from the repetition of similar seismic disturbances. The separate occurrences of the two successive destructive earthquakes have no doubt materially contributed to diminish the amount of the seismic damage which ought to have been produced had the the two shocks been combined in one occurrence.

The frequency and intensity of after-shocks of a destructive earthquake usually show periodic variations with the lengths, amongst the others, of 4½ days and 8–9 days. In the present instance, the after-shocks of the two destructive earthquakes on the 11th steadily decreased in frequency; with none of the *strong* intensity after the 14th. A somewhat strong after-shock took place, however, on the 20th, at 9. 48. 55 A.M., namely, 9 days 7 hours after the 1st earthquake. Again, after an interval of 4 days 19 hours, a pretty severe after-shock took place on the 25th, at 4. 56. 55 A.M. After a further interval of 5 days 23 hours, again took place a strong after-shock on Dec. 1st, at 4. 15 A.M. Then, after an interval of 13 days (equivalent to the sum of 4½ and 9 days), occurred a fairly strong shock on Dec. 14th, at 5. 34 P.M. These show the two average intervals of approximately 4½ and 9 days in conformity with the general time distribution of after-shocks. The occasional occurrence of comparatively strong after-shocks at Omachi was thus a matter of no extraordinary seismic behaviour. This fact was recognized by the author already at the time of his visits to the shaken districts and pointed out to the panic stricken people as one of the reassuring circumstances.

5. EARTHQUAKE DAMAGE. The earthquake damage was chiefly limited to the town of Omachi and the 5 neighbouring villages of Tokiwa (常盤), Yashiro (社), Taira (平), Yasaka (八阪), and Mima (美馬), in the central and southern parts of the Kita Atsumi district, province of Shinano (prefecture of Nagano), the first named 4 places having suffered most severely. There was no case of casuality, except one man wounded at each of the villages of Tokiwa, Yasaka, and Aisome, and two at Mima. According to the census of the Kita Atsumi district office, the total seismic damage, relating to the towns of Omachi and Ikeda and of Yashiro and 9 other villages, was as follows:—

Number of the dwelling houses totally destroyed	6
,, ,, ,, half destroyed	2,852
,, ,, *dozo*, ware-houses, etc., totally destroyed	16
,, ,, ,, ,, damaged	2,273
,, public buildings, temples, etc., damaged	290
Roads and river embankments, cracked	7365 metres
Ishigaki (stone retaining walls) damaged	334 places.

The dwelling houses totally destroyed were either old rotten buildings or converted ware-houses, none of the houses in ordinary condition of keeping having collapsed. Hereby it is to be noted that most of the Japanese style houses in Omachi and the vicinity are low, even the two-storied buildings looking like 1½-storied ones. In this connection it may be stated that after the great Zenkoji (Nagano) earthquake of 1847, it has been prohibited in the city of Nagano to build 2-storied houses, on account of the great risk to which the tall wooden buildings were exposed on occasion of destructive earthquakes. The maximum height of vertical posts to be allowed in the one-storied houses was fixed at 11 *shaku**, the limit having subsequently been raised to 2½ *ken* (=15 feet). It is probable that the low structures in the Omachi district were the result of a similar seismic precaution, as the town and some of the neighbouring villages suffered not in an insignificant degree the effect of the Zenkoji (1847) and the Ansei (1854) earthquakes. The comparatively small amount of damage done to the houses in the present case was also doubtless due to the employment of thick strong wooden posts. The statistical statements of the seismic damage for the different towns and villages are given in Table I.

Table I. List of Seismic Damage in the different Towns and Villages.

Town or Village.	Number of Dwelling Houses.			Dozo, Ware-houses, etc.		Schools, Temples and Public Offices, damaged.	Number of damaged Ishigaki (stone wall).	Length† of	
	Totally destroyed.	Half destroyed.	Damaged.	Totally destroyed.	Damaged.			Roads damaged.	Rivers damaged.
Omachi (大町)	—	241	867	6	692	84	228	ken 302	ken 2566
Yashiro (社村)	4	16	270	7	350	18	57	1242	570
Tokiwa (常盤村)	1	28	585	—	476	11	3	120	—
Matsukawa (松川村)	—	—	—	—	13	2	—	—	—
Ikeda (池田町)	—	—	7	—	42	1	—	—	—
Aisome (會染村)	—	—	3	—	14	2	4	—	—
Nanaki (七貴村)	—	2	—	—	—	8	—	—	—
Rokgo (陸郷村)	—	1	370	—	386	—	—	—	—
Hirotsu (廣津村)	—	1	1	1	3	6	2	60	—
Yasaka (八阪村)	1	9	67	2	71	7	36	226	200
Taira (平村)	—	3	309	—	188	6	2	25	8
Mima (美麻村)	—	4	68	—	33	145	—	20	—
Sum.	6	305	2574	16	2273	290	334	1507	3344

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* 1 *shaku* = 0.997 English foot.

† Expressed in *ken* = 6 *shaku* = 6 feet very nearly.

A special feature in the Omachi earthquake damage was an enormous amount of the cracks and shaking down of the plastered mud walls of the dwelling houses and the *dozo* (wooden-frame ware-houses with thick plastered mud walls). In fact the seismic disturbances may, as far as the damage is concerned, termed as "*dozo* earthquakes." The chief fault of construction lies in the inferior quality of the wall mud, which is made up of incoherent sandy earth mixed with a small proportion of clay. For the structures in Omachi and the villages of Yashiro and Tokiwa, the clay must be imported from other places, and the high cost of transportation reduces sometimes the use of the clay to only 10 or 20% in the preparation of the wall mud. Another objectionable custom in the construction of the *dozo* walls is the employment, not of the bamboo pieces as they do in other parts of Japan, but of thick round rods of wood, sometimes 1″ or 2″ in diameter, for the internal framing of the walls. These are arranged vertically and horizontally and are tied at their crossings with straw ropes, and then plastered over to the thickness of about 6″ by the mud mixture above mentioned. Thus it follows that the mud walls are at the time of a destructive shocks very easily cracked and shaken down in large masses. On the other hand, it may be that this very circumstance, taking off the heavy weight from the buildings, actually saved the latter from being totally overthrown by the earthquake motion.

6. COMPARISON OF THE TWO DESTRUCTIVE SHOCKS ON NOV. 11TH. The two earthquakes on the 11th, at about 3 A.M. and about 4 P.M., had different meizoseismal areas. Thus at Omachi the 3 A.M. earthquake was very strongly felt, almost to the same degree as the 4 P.M. earthquake. At the temple Reishoji situated on a hill of diluvial formation about 1.5 km. to the N. E. of Omachi, the 3 A.M. shock was strong and caused the overthrow of the several *ishidoro* (stone lanterns). It was, however, at the 4. P.M. shock that the sandy cliffs fell down and blocked the road ascending to the temple. At the village of Kirikbo (切久保), 3.5 km. to the E. slightly S. of Omachi, the 3 A.M. shock caused considerable damage to the *ishigaki* of the different houses and threw out of perpendicular the elementary school, a 2-storied wooden building, which had also its wall mud shaken down, window panes broken, and the wooden stair-case deranged out of position ; the 4 P.M. shock which was a little stronger, having caused no special further damage. At the temple of Yamashita Myojin in the Jokoji locality of the Yashiro-mra, about 2.5 km., to the S.E. of Omachi, all the ordinary *ishidoro* were overthrown by the 3 A.M. shock. In the same compound, the pedestal of a stone lantern was found displaced to the extent of 17cm., while the wooden *torii* (Shinto gate) suffered a displacement of 20 cm. off the foundation stones.

These latter effects seem to be due to the 4 P.M. shock. At the Matsuzaki locality of the Yashiro-mra, adjoining the S.E. part of the town of Omachi, the 3 A.M. shock caused the crack of walls and the overthrow of the *ishidoro ;* it being chiefly, however, the 4 P.M. earthquake which caused damage to the *ishigaki*. At the Nakabayashi locality of the same village, where the soil is low and moist, the motion was very violent, as may be judged from the following facts :— a large manure tub, 3 feet in diameter and 3 feet in depth, buried in the ground was thrown by the shocks 1.5 feet vertically out of the latter. Subsequently it subsided 0.5 foot by itself. At the village of Mikkamachi, 2 km. to the N. slightly E. of Omachi, the 3 A.M. shock was very strong and caused much cracking of the *dozo* walls, which were in most cases finally shaken down by the 4 P.M. shock. Again the two ware-houses, somewhat thrown out of the vertical by the 3 A.M. shock, were thrown down by the 4 P.M. shock.

At the Osaki, Shimizu, and Ippongi localities of the Tokiwa-mra, about 6 km. to the S.W. of Omachi, the 3 A.M. shock was only slightly felt and it caused no damage, such that no peaple ran out of the doors, and even very unstable tomb stones and stone-lanterns were not overthrown. On the other hand, the 4 P.M. shock was very strong at these places, causing, amongst the others, at Shimizu the displacement of the pedestals of the tomb stones to the maximum horizontal amount of 3′ 2.″5.

From the above accounts it will be quite evident that the two destructive earthquakes on Nov. 11th had different foci. The first (3 A.M.) shock was strongly felt, with production of marked damage, only within an area, 4 km. in diameter, including the town of Omachi and the adjacent places to its N., E., and S. E. The second (4 P.M.) shock was of a much greater magnitude and was felt most strongly in the Tokiwa-mra localities; its intensity of motion in the meizoseismal area of the first earthquake being also higher than on that occasion.

7. POSITIONS OF THE EARTHQUAKE ORIGINS DEDUCED FROM TOKYO OBSERVATIONS. The two Omachi earthquakes under consideration have been felt slightly in Tokyo. The results of the tromometer observations at the Seismological Institute were as follows :—*

1st Earthquake.

Time of Occurrence = 2. 58. 48 A.M.

Duration of Preliminary Tremor = 25.8 sec.

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* The radial distance from the observing place (=x km.) has been calculated from the duration of the preliminary tremor (=y sec.) by the formula : x km. = 7.42 y sec.

Radial Distance=191 km.
1st Displacement of the earthquake motion=0.12 mm.
directed originward.
Mean Direction of motion in Prel. Tremor=N.63°.9W.
Maximum Motion=3.3 mm.

2nd Earthquake.

Time of Occurrence=4. 03. 40 P.M.
Duration of Preliminary Tremor=26.8 sec.
Radial Distance=199 km.
1st Displacement of the earthquake motion=0.55 mm.
directed originward.
Mean Direction of motion in Prel. Tremor=N. 66°.6W.
Maximum Motion=11.8 mm.

Thus the origin of the 1st earthquake was situated 191 km. to the N.63.°9W. of Tokyo, and that of the 2nd at 199 km. to the N.66°.6W. of Tokyo. These positions are close to Omachi, the 2nd origin being located about 8 km. to the S.W. of the 1st origin. (See fig. 11.)

8. POSITIONS OF THE EARTHQUAKE ORIGINS DEDUCED FROM NAGANO OBSERVATIONS. The portable type horizontal pendulum tromometer, of pointer magnification=75, at the meteorological observatory of Nagano, where the earthquakes were felt as *strong* motion,* has given satisfactory registers. (See Pls. VI and VII.)

On account of the short distance the Nagano records fix the positions of the centres of disturbances with accuracy. The results of the observations were as follows :—

1st Earthquake.

Time of Occurrence=2. 58. 13 A.M.
Duration of Preliminary Tremor=4.7 sec.
Radial Distance=35 km.
1st Displacement=0.17 mm., directed originward.
Mean Direction of motion in Prel. Tremor=S.60°.4W.

2nd Earthquake.

Time of Occurrence=4. 03. 12 P. M.
Duration of Preliminary Tremor=5.2 sec.

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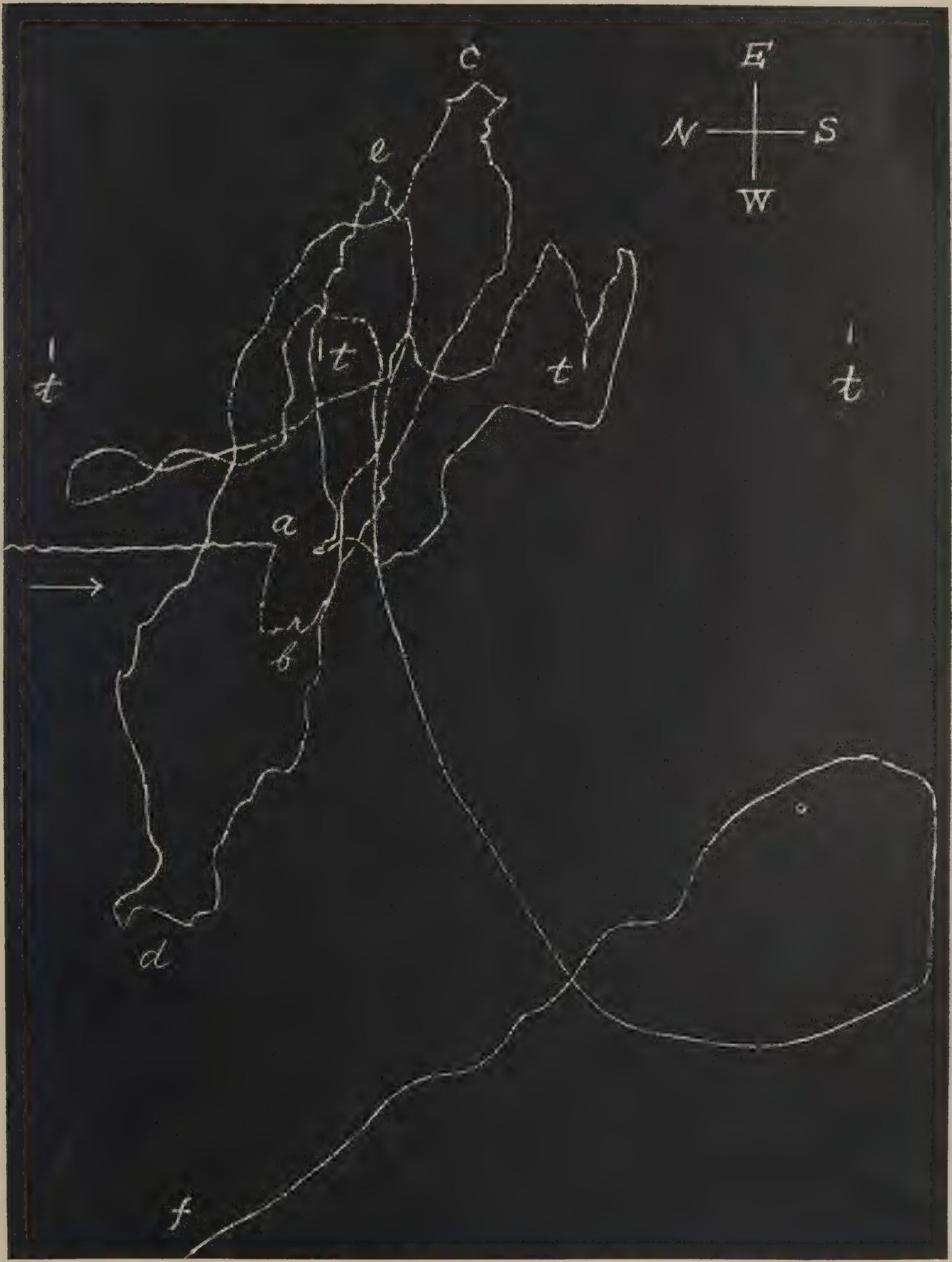
* The earthquake motion of *strong* intensity is one which is felt strongly, but which causes no damage.

Fig. 6. The 2nd Destructive Omachi Earthquake, on Nov. 11, 1918, at 4 P.M.

Duplex Pendulum Tromometer Record at Tokyo. Multiplication = 23.



a ......Commencement.	*ab*......1st Displacement.
bc......2nd Displacement.	*cd*......3rd ,, .
de......4th ,, .	*t* ......*t*, successive minute marks.

(The writing pointer got out of the smoked paper at *f*.)

Pl. V.

Tokyo Observation of the Omachi Earthquakes.

Duplex Pendulum Tromometer Records Multiplication = 30.

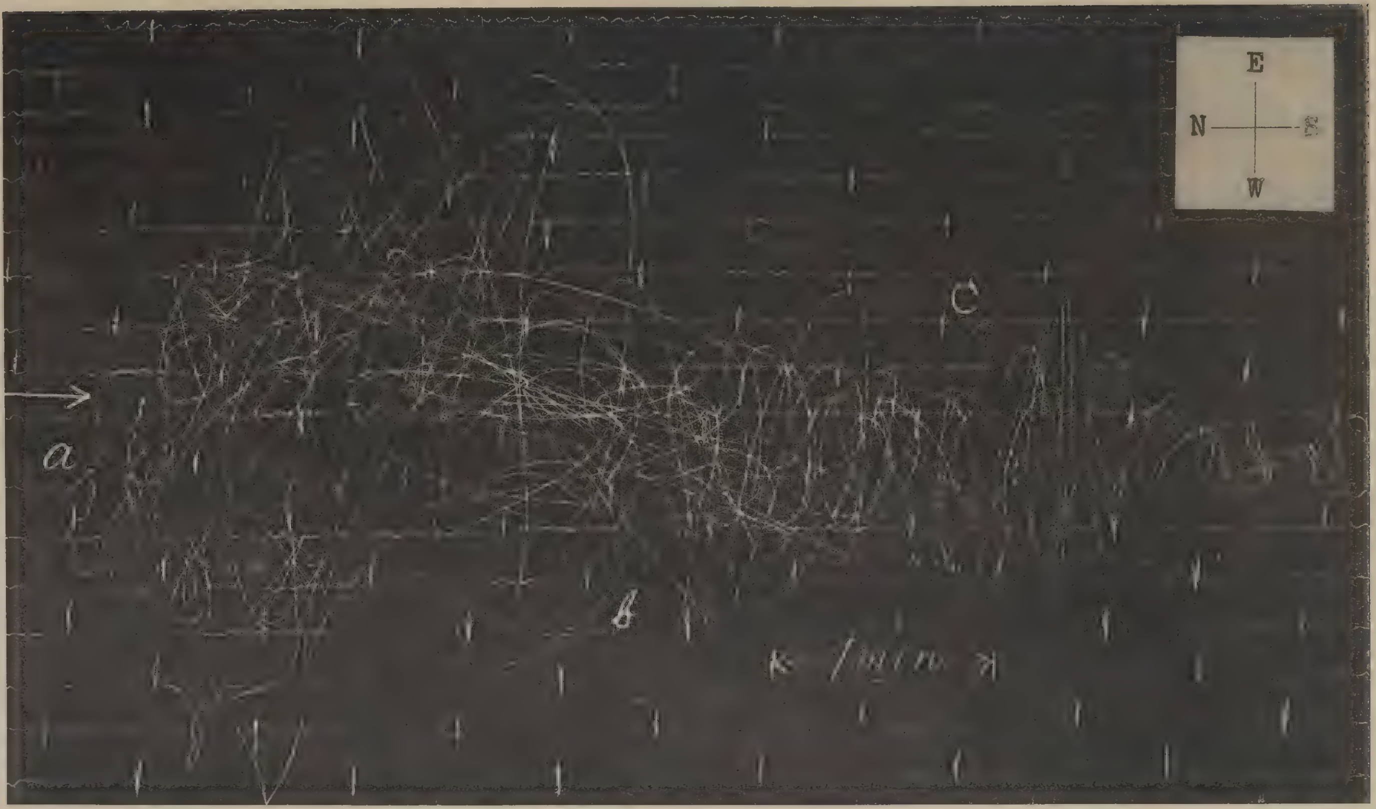


Fig. 7. The 1st Destructive Earthquake, on Nov. 11, 1918, at 2.58 A.M.

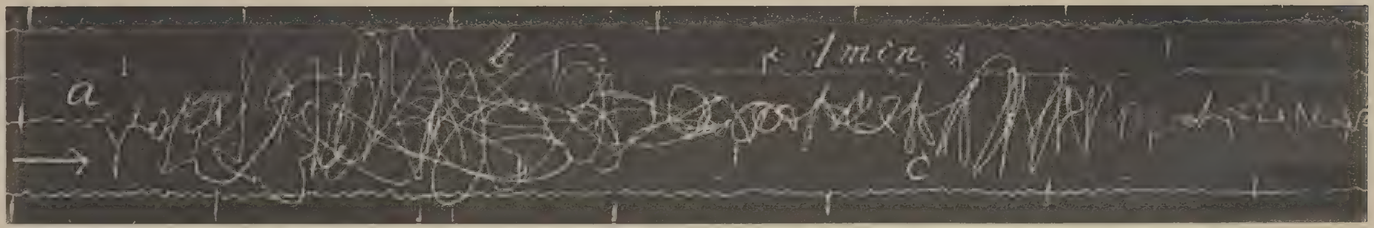


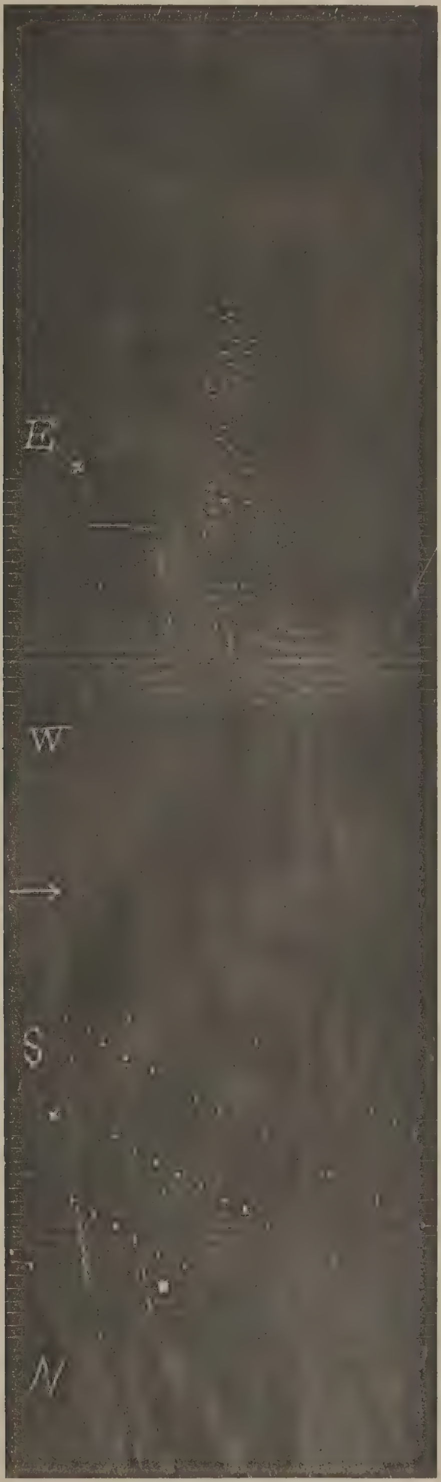
Fig. 8. The Strong Aftershock on Nov. 11, 1918, at 3.16 A.M.

Pl. VI.

Fig. 9. The 2nd Destructive Omachi Earthquake, on Nov. 11, 1918, at 4.03 P.M.

Horizontal Pendulum Tromometer Record at the Nagano Meteorological Observatory.

Multiplication = 62.

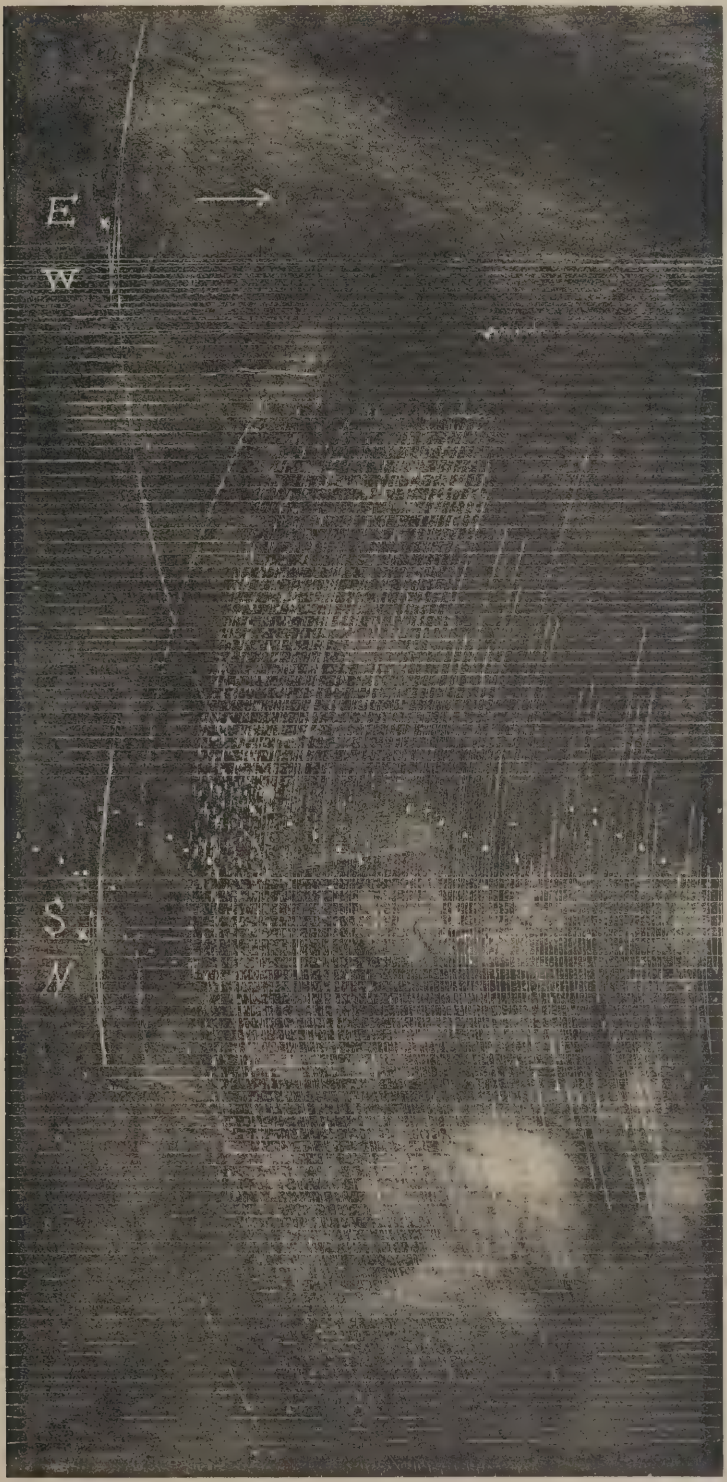


(×)......Earthquake Commencement.

Small white dots are successive minute marks.

Fig. 10. The 1st Destructive Omachi Earthquake. on Nov. 11, 1918. at 2.58 A.M.

Horizontal Pendulum Tromometer Record at the Nagano Meteorological Observatory.
Multiplication = 60.



(×)......Earthquake Commencement.
Small white dots are successive minute marks.

Radial Distance = 39.3 km.
1st Displacement of the earthquake motion = 0.32 mm.
Direction of the 1st Displacement = S.55°.4W.

The origin of the two destructive earthquakes were thus respectively 35 km. to the S.60°.4W. and 39.3 km. to the S.55°.4W. from the meteorological observatory of Nagano. These distances, representing the radial distances, must be some 1 km. greater than the corresponding epifocal radii. The epicentres thus determined (fig. 12.) coincide almost exactly with the actual positions determined from the field study. (See fig. 2.)

Both from the Tokyo and the Nagano tromometer observations it may be concluded that the 2nd earthquake was at least twice so large as the 1st.

9. TROMOMETER DIAGRAMS. Figs. 6 to 8 are reproductions of the duplex pendulum tromometer register of the two destructive earthquakes and their strongest after-shock observed at the Seismological Institute (Tokyo), each giving the resultant horizontal motion with magnification. In the 2nd destructive earthquake, whose motion was large and caused the writing pointer to be thrown out of the smoked paper at the commencement of the principal portion, the initial displacement was clearly directed toward the seismic origin, the average direction of motion in the prelimary tremor being N.66°.6W. and S.66°.6E. In the case of the 1st destructive earthquake and the after-shock, the motion was smaller and was registered completely, without throwing the pointer out of the smoked paper. In figs. 7 and 8, *a* marks the beginning of the earthquake motion, and the interval of about $1^m 50^s$ between *a* and *b* belongs to the longitudinal wave. The latter class of movement was again markedly indicated at *c* about $4^m 12^s$ after the start. This second group of the longitudinal wave was also shown in the Tokyo seismograms of the strong Asama-yama earthquake of July 16, 1912, where the time interval between its appearance and the commencement of the earthquake motion was $3^m 35^s$.* The second longitudinal group whose propagation velocity was very low and amounted to some 0.6 km. per sec., may be the effect of the propagation of seismic disturbances through the inner magmatic mass.

Figs. 9 and 10 represent the portable tromometer registers at the Nagano meteorological observatory. The initial displacement pointed in each case clearly toward the origin.

10. CRACKS AND SLIGHT DEPRESSION OF GROUND. In the Omachi earthquakes in question there was no surface manifestation of well defined faults or dislocation of the ground. There were, however, some cracks of long extension with an accompaniment of vertical disturbances. Thus in the Tokiwa-mra district the crack 2″.5 in maximum width stretched in the direction of N.30°E.—S.30°W., through the village ground and mulberry fields, for the distance of about 1 km. from Osaki to a place called Butai and thence further to Nagabata, where a landslip was produced; there being at some places several lines formed parallelly within the breadth of 10 to 20 feet. The crack zone indicated the area of a slight relative depression, of maximum amount 6″, always on its E.S.E. side. Again another crack, 1″ in width, was formed in the direction of N.73°W. and S.73°E. for the distance of 400 metres across the cultivated field to the south of Shimizu temple in the Shimizu district of Tokiwa-mra, with a slight depression of 1″ to 2″ on its N.N.E. side. (See fig. 2.) These two crack lines were different from the ordinary fissures formed along roads, river banks, or cliffs, and may be supposed to mark the western boundary of the area of apparent depression, being the result of the level disturbances at the epicentral area.

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* See the Bulletin of the Imp. Earthq. Inv. Comm., 7, No. 3, Pl. XLIV.

11. **DIRECTION OF MOTION IN THE EPICENTRAL AREA.** At the localities of Reishoji, Jokoji, and the Yamashita temple, in the meizoseismal area the stone-lanterns were overturned by 3 A.M. shock on the 11th, while the displacement of the pedestals and temple gates took place on the occasion of the 4 P. M. shock on the same day. Again, the overturning and other seismic damage at the different districts of the Tokiwa village were entirely due to the 2nd earthquake. The mean overturning and sliding directions at different places in the strongly shaken area were as follows.

Reishoji Temple. By the 3 A.M. earthquake were overturned a cylindrical stem stone lantern toward N.15°E. and 6 square stem stone lanterns toward S.6°E.; S.5°W.; N.9°E.; S.45°W.; S.30°W. Fifteen circular section tombstones were overturned toward S.20°W.; S.20°W.; S.40°W.; S.40°W.; S.40°W.; S.20°E.; S.20°E.; N.25°W.; N.15°W.; N.20°W.; N.20°W.; S.15°E.; S.15°E.; S.35°E.; S.10°E. A shed consisting of a roof supported by 4 posts was thrown toward S.20°W. In the 4 P.M. earthquake there were three cases of sliding of pedestals of stone lanterns, respectively toward N.; N.; S.71°E.

Matsuzaki. 4 stone lanterns were overturned toward S.E.; S.E.; S.5°W.; S.40°W. The roof covering of a dozo was overthrown toward N. A stone monument structure was thrown toward S.

Omachi. At the Omachi station of the Matsumoto and Omachi Light Railway (gauge=3′ 6″) in the southern part of the town, a train without engine, and composed of 6 cars, with the breakvan secured, was lying along the platform parallel E.-W.; the two goods wagons at the end being each 18′

long and 7′ wide. By the earthquake shock at 4 P.M. the last car, 4.75 tons in weight, was thrown 0.65 foot off the rails and landed on the sleepers toward the S. The last but one car, 4.86 tons in weight, was also partly derailed toward the same side. The rails of 40 lbs. type were 3″.5 in height, the top width being $1\frac{1}{8}''$.

At the Dansei-ji temple（彈誓寺）in the S.W. part of Omachi, 5 stone-lanterns were overturned toward S.35°E., S.8°E., N.12°W., S.35°E., S.65°E., while tomb stones were overturned as follows :— 26 toward W., 6 toward E., 6 toward S., and 4 toward N. In two cases the sliding took place toward N. and toward N.70°E. At another temple, the Tensho-ji（天正寺）in the same part of the town, the directions of overturning of 12 stone-lanterns and tomb stones were : S.E., E., E., S., S., W., E., S., E., W., W., and N.60°E. The sliding took place in two cases toward S.E., and toward S.31°E.

At the Oji temple（王子若一ノ宮）in the northern part of Omachi, 4 stone lanterns had their round ball tops thrown respectively toward S.20°W., S.10°E., N.8°W., and S.55°W. Three stone lanterns were overturned toward E., S.40°E., and S.70°E. In one case the sliding took place toward S.55°W. The stone temple fence was uniformly thrown toward the E. by the 4 P.M. earthquake. At a street corner nearby 2 stone lanterns were overturned toward E. and toward W., by the 3 A.M. earthquake.

At the temple Rokkakdo（六角堂）immediately to the S. of Omachi, the sliding of a tomb stone pedestal was directed toward S.57°E.

Matsuzaki. 4 stone lanterns were overturned toward S.E., S.E., S.5°W., and S.40°W. A small stone shrine was overthrown toward S.

Yamashita temple, Jokoji. By the first earthquake, two cylinder-stem stone lanterns were overturned toward N.35°W. and S.63°W., and six square-stem ones toward N.25°E., N.15°E., N.10°E., S.55°W., N.5°W., and N.60°E. The direction of the sliding caused by the second earthquake were as follows :— the pedestals of two stone-lanterns displaced toward N.56°E. and N.E.; a wooden *torii* (Shinto gate) displaced toward E.

Table II. Direction of Overturning and Displacement of Bodies.

Locality.	1st Earthquake. (2.58 A.M.)	2nd Earthquake. (4.03 P.M.)	
	Overturning.	Displacement.	Overturning.
Reishoji (靈松寺), N.E. from Omachi.	S.	S.75°E.	—
Omachi (大町), W. and S. parts.	S.35°W.	E.	—
Omachi Railway Station.	—	(Two cars of a train at rest derailed towards the S.)	
Oji (王子若一宮), N. from Omachi.	S.35°W.	—	S.72°E.
Rokkakdo (六角堂), S. „ „	S.40°E.	S.62°E.	—
Ohara (大原町), N.W. „ „	S.14°E.	—	—
Matsuzaki (松崎), Yashiro-mra.	N.19°E.	—	—
Jokoji (常光寺) , „	N.19°E.	N.65°E.	—
Kirikbo (切久保), Yasaka-mra.	—	—	N.45°W.
Ippongi (一本木), Tokiwa-mra.	—	N.	N.E.N.
Shimizu and Nakahara, (清水, 中原)	—	N.80°E.	S.58°E.
Shingyo (新行), Mima-mra.	—	N.45°E.	E.

Tokiwa-mra. The overturning and sliding in the village districts of Tokiwa were due entirely to the earthquake shock at 4 P.M. on Nov. 11. At the cemetery of Shimizu (清水), the directions were as follows:— 1 cylinder-stem stone lantern was overturned toward N.75°E.; nine tomb stones were overturned toward N.75°E., E., S.10°E., S., E.70°N., S., S.S.E., N.70°W., and S.20°W.; the pedestals of six tomb stones were displaced toward N.75°E., E., N.75°E. (to the amount of 3.2 feet), N.55°E., E., and N.60°E. At the Shimizu temple, a circular section tomb-stone was overturned toward S.40°W., while the sliding of a pedestal amounted to 0.3 foot toward S.20°W. At the Mishima temple (三島神明社), 4 cylinder stem stone lanterns were overturned toward S.25°E., N.70°W., S.20°W., and N.23°W., while the displacement directions were N.W., W., and N.30°W. At Nakahara (中原) three tomb stones were overturned all toward the N.E. At the Ippongi (一本木) temple, two square-stem stone lanterns were overturned toward the N. and N.E., while a sliding took place toward the N.

The mean directions of motion at the different places are given in Table II and are graphically indicated in fig. 2. With respect to the 1st earthquake the direction of overturning of bodies has been assumed to represent the direction of the maximum earthquake displacement.

12. ORIGINS OF THE EARTHQKEUAS. In the 1st earthquake, the maximum motion was directed principally toward S. or S.E. at Omachi, Reishoji, Matsuzaki, and the vicinity, while it was toward N.N.E. at Jokoji. From this variation in the direction of motion coupled with the position of the strong motion area before described, the origin of the earthquake in question may be located to the N. of Jokoji and to the S.E. of Matsuzaki, namely, some 2 km. to the S.E. of the district office of Omachi, at the point marked P_1 in fig. 2. (Pl. II).

On the other hand, in the 2nd earthquake, the directions of motion at the different places do not converge toward a common centre but are directed generally toward the east. Now an approximate parallelism or a more or less parallel symmetry of the direction of motion about a horizontal line may be taken as one of the consequences of the geological dislocation or fault formation at the seismic origin. Further, in the present instance, there was no special difference in the intensity of motion at the Shimizu locality of the Tokiwa village and at the Matsuzaki and Jokoji localities of the Yashiro village, separated by a distance of about 6 km. to the N.E. from the former; the shock in the meizoseismal area being reported as having been essentially horizontal. From these considerations the 2nd earthquake seem to have been caused by an underground disturbance having the line P_1 P_2 (fig. 2.) for its axis. From the direction of motion it may be assumed that the ground about the town of Omachi had been gradually pushed toward the S.W. and reached the limit of stress, when the sudden dislocation finally took place, causing first a displacement toward the same direction, followed by a greater counter motion toward the opposite direction. The vertical disturbance which accompanied this action, probably resulted in the formation of the cracks and the relative depression at Osaki and Shimizu. The origin (P_1) of the 1st earthquake is situated on the axial line P_1 P_2. The main centre of the 2nd earthquake, whose focus extended over the whole length of the latter, seems to be the vicinity of the point P_2. The axis P_1 P_2 forms evidently the S.W. continuation of the Shinano-gawa valley earthquake zone (fig. 1).

13. RECORDS OF OLD OMACHI EARTHQUAKES. The town of Omachi and the vicinity suffered more or less from the great Zenkoji earthquake on May 8, 1847, the great Ansei earthquake of Tokaido on Dec. 23, 1854, and the Matsushiro earthquake on April 23, 1858. At the time of the first named earthquake, the Reishoji temple, on the flank of the sandy hill of the same name, $1\frac{1}{2}$ km. to the N.E. of Omachi, was overthrown and burnt.

At the times of the two latter earthquakes, the after-shocks lasted for several weeks, and the people of Omachi passed more than 10 days in temporary shelters. In these cases, however, Omachi has simply been affected by distant destructive shocks, and not by one properly belonging to the region about the town. As an instance of the latter may be mentioned the Omachi-gumi earthquake in the 4th year of Shotoku (1714).

Earthquake of 1714. The earthquake occurred on April 28, 1714, at about 10 P.M., and was strong in the old so-called Omachi-gumi, or the district under the jurisdiction of Omachi, which included 54 villages in the northern part of the Kita-Atsumi county (province of Shinano) to the east of the river Takase; the total amount of damage amounting to 300 houses totally or partially destroyed, and 56 persons and 46 horses and cattle killed. The motion, which was felt strongly also at the city of Matsumoto, proved destructive at places between the lake of Aoki and the boundary of the province of Echigo in the narrow valley stretching northward from the plain of Omachi through the region of the lakes of Kizaki, Nakatsuna, and Aoki, to the course of the river Hime-kawa. In Chikni-mra（千國村）the mountain flanks at Tsubono-sawa（坪之澤）slid down and buried the houses and the cultivated fields, killing 30 persons and 8 horses and cattle. At Horinouchi（堀之內）, 48 houses were destroyed, killing 14 persons and 36 horses and cattle. The number of the houses destroyed was 2 at Uchu（谷中村雨中）; 4 at Kruma-mra（來馬村雨中）; 4 at Miyamoto; 6 at Kdarise（土谷村下リ瀨）; and 2 at Yoshiwo（同村由尾）. The Hime-kawa was inuandated, washing away several houses. The earthquake origin seems to have been situated about 10 km. to the N.N.E. of the lake of Aoki.

Iiyama and Matsushiro earthquakes. Four and half years later took place on Oct. 5, 1718, a local destructive earthquake which caused damage at and about the town of Iiyama in the extreme N.E. part of the province of Shinano. More recently there occurred on April 23, 1858, at 8. A.M. another local shock, some distance to the S.E. of the city of Nagano, which caused damage at and about the town of Matsushiro. These two shocks must have been geographically related to the Omachi-gumi earthquake of 1714, although the origins were mutually apart by distances of 35 to 50 km.

14. ZENKOJI CATASTROPHE AND SHINANO-GAWA VALLEY SEISMIC ZONE. The Shinano-gawa valley forms an active seismic zone, along which occurred recently in succession the three great earthquakes of Sanjo, in Echigo (1828), of Sado and Uzen (1833), and of Zenkoji (1847)*.

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* See the Bulletin of the Imp. Earthq. Inv. Comm., **1**, No. 3, and **2**, No. 2.

Of these the last was an extensive and an unusually violent seismic disturbance, being much greater than the two others.

15. LOCAL DESTRUCTIVE SHOCKS AND THE SEISMIC ZONE OF HIME-KAWA AND TENRYU-GAWA. Beside the three great earthquakes mentioned in the preceding §, there were other strong shocks in the province of Shinano, as indicated in the following table.

Date.		Strongly Shaken District.
		[Earthquakes in Recent Years.]
(a)	July 23, 1886.	Minuchi (and Higashi Kbiki, in Echigo).
(b)	Jan. 7, 1890.	Kami-Minuchi, Higashi-Chikma, Kita-Atsumi, Sarashina.
(c)	Jan. 17, 1898.	Kami-Takai, Kami-Minuchi.
(d)	Jan. 22, 1899.	Suwa, Kami-Ina, Higashi-Chikma.
(e)	Aug. 17, 1912.	Ueda and vicinity.
		[Earthquakes in Old Times. § 14.]
(f)	April 28, 1714.	Omachi-gumi, in the N. part of Kita-Atsumi District.
(g)	Oct. 5, 1718.	Iiyama and vicinity.
(h)	April 23, 1858.	Matsushiro and vicinity.

All of the earthquakes above tabulated were of the catagory of local destructive shocks and far smaller than the Zenkoji earthquake of 1847. The origins of the three disturbances (b), (d) and (f) belong together with that of the strong earthquake of May 18, 1917, in the Shizuoka prefecture, to an earthquake zone extending in the N. and S. direction along the courses of the rivers Hime-kawa and Tenryu-gawa flowing respectively toward north and toward south, on the eastern base of the high mountain range of the Japan Alps. This Hime-kawa and Tenryu-gawa seismic zone is much weaker in energy than the Shinano-gawa valley seismic zone.

16. RELATION TO THE ZENKOJI EARTHQUAKE. The great violence and extension of the Zenkoji earthquake of 1847 was probably due to its occurrence at the intersection of the two seismic zones of the Shinano-gawa valley and of the Hime-kawa and Tenryu-gawa valley, and it is noteworthy that the origins of all the other seismic disturbances in the province of Shinano tabulated in the preceding § were situated around the area of the strongest motion of the Zenkoji earthquake. In other words, the latter forms a seismic disturbance of fundamental or primary importance causally related to the other destructive earthquakes, both recent and old, which may be regarded merely as geotechtonic events of secondary or auxiliary magnitude. We may presume, therefore, the Zenkoji earthquake to be equivalent to the removal of the main seismic instability existing in this part of the earth's crust, such that the future destructive shocks in and about the region in question will be local in nature and not be excessively violent in intensity. The two Omachi earthquakes on Nov. 11, 1918 also belong to the same class of the seismic manifestation. The frequent occurrence of the comparatively strong after-shocks in the present instance may probably be traced to the secondary nature of the two chief earthquakes themselves.

17. DESTRUCTIVE MOTION AREA. The area within which took place more or less damage to buildings, cracks of the ground, landslips, etc. extended to the lake of Kizaki and the village of Aogai on the north, to the river Sai-gawa on the east, to the Tokiwa-mra and town of Ikeda on the south, and to Rikgo-mra and Aisome-mra on the south-east. The maximum extension was 26 km. in the N. S. direction from the valley districts of the lakes of Kizaki and Aoki and of the Takase river to the eastern hills of Tertiary formation, and to over 16 km. in the E.W. direction from the Sai-gawa to the granite mountains to the west of Omachi. To the west of the Takase-gawa, the ground is hard and is composed of sand and granite masses, the shock being there light except in the vicinity of the epifocal region.

Outside the above-mentioned area, slight damage was produced in a few places, as follows :— At Minuchi-mra, Kamiminuchi district, some roof tiles fell down, wall plasters were shanken off and sliding glass doors were thrown out of their grooves, while at a place called Kokra was formed a ground crack 20 ft long and 2″.5 wide. At Miyamasato (Hisato-mra) in the same district a two-story *dozo* ware-house 12′ × 24′ in size was thrown down. At Ooka-mra, in Sarashina district, some rock masses were detached from cliffs by the earthquake at 4 P.M.; no damage being done, however, to buildings. It is likely that the Minuchi-mra localities, lying to the N.E. of the epifocal area of the Omachi earthquakes, were shaken with a comparatively strong intensity on account of their location on the Shinano-gawa valley seismic zone.

18. AREA OF SENSIBLE MOTION. The shock at 3 A. M. on Nov. 11, 1918 was strong within a circular area, about 75 km. in diameter, extending from Iiyama on the north to Matsumoto and Shiojiri on the south, and from the vicinity of Komoro on the east to the confines of the Japan Alps on the west. The motion was, however, felt slightly or weakly within a long narrow zone stretching on the whole along the valleys of the rivers Shinano, Kiso,

Fig. 11. Positions of the Epicentres of the Two Destructive Omachi Earthquakes on Nov. 11, 1918, determined from the Tromometer Observations in Tokyo.

I……Epicentre of the 1st Destructive Shock.
II…… " " 2nd " "

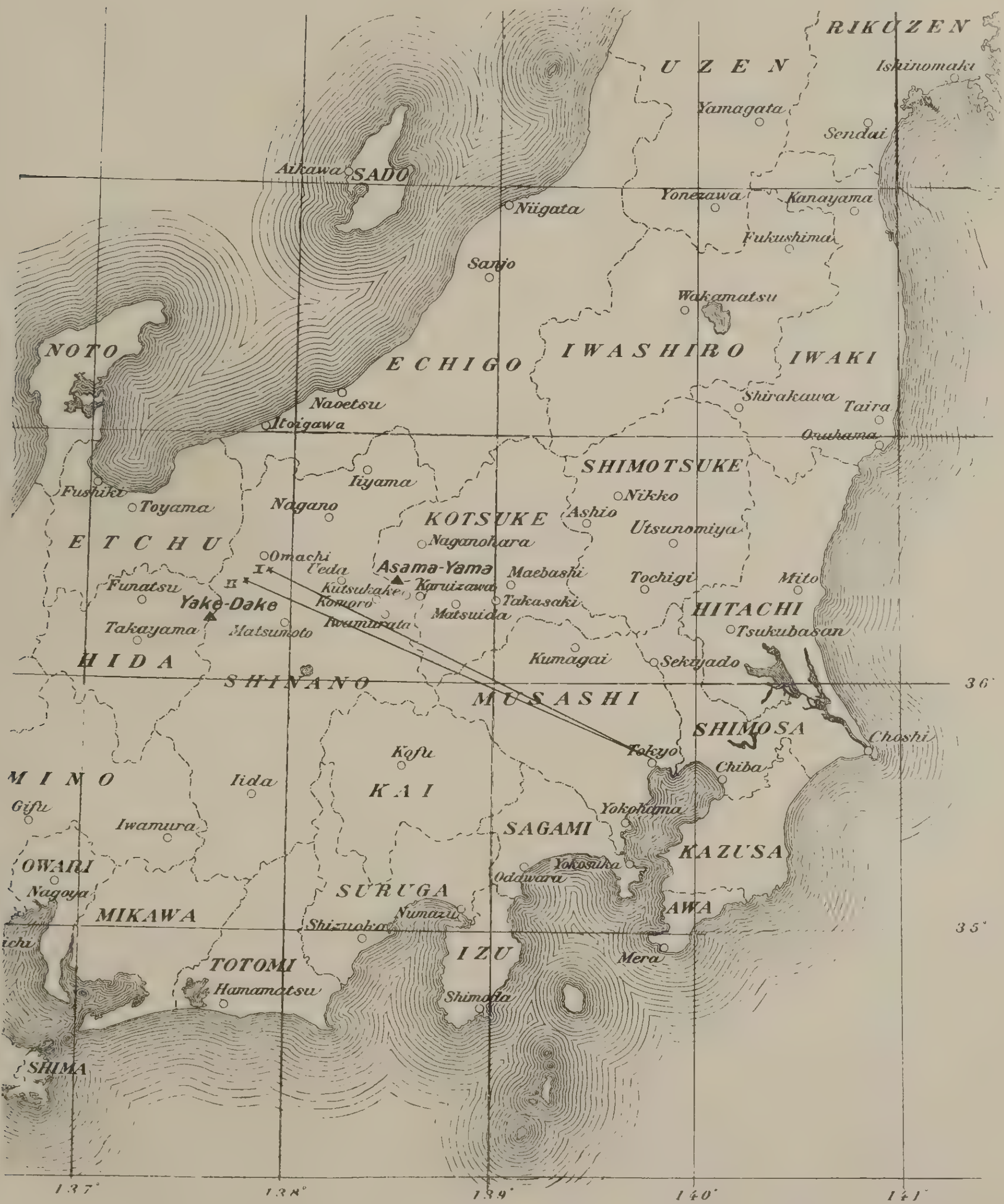
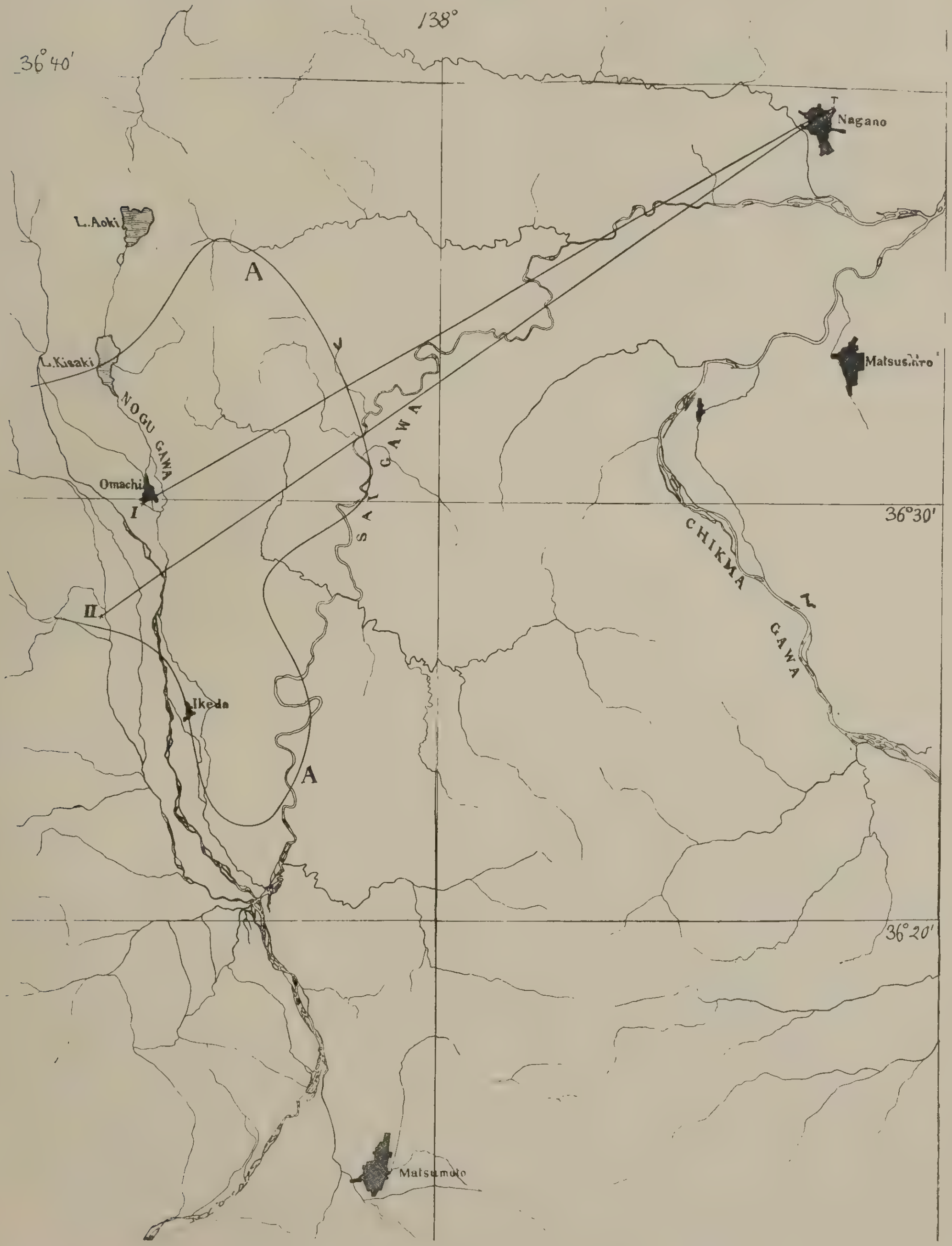


Fig. 12. **Positions of the Epicentres of the Two Destructive Omachi Earthquakes on Nov. 11, 1918, determined from the Tromometer Observations at Nagano.**

T......Nagano Meterological Observatory.
I......Epicentre of the 1st Destructive Shock.
II...... „ „ 2nd „ „



The curve **AA** indicates the area of destructive motion.

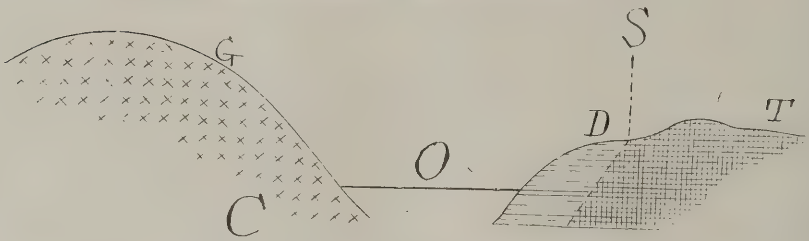
and Tenryu, for the extension of about 450 km. from Niigata on the north to the provinces of Owari, Mikawa, and Totomi on the south. This marked elongation of the earthquake area was probably due to the facility of the seismic propagation along the Shinano-gawa valley and the Hime-kawa and Tenryu-gawa seismic zones.

The strong earthquake on Jan. 12, 1919, at 10 P.M., which caused some damage at Hamamatsu, Shizuoka and the vicinities, originated in the Tenryu-gawa valley at the central part of the province of Totomi, immediately to the south of the centre of the destructive earthquake of Shizuoka prefecture on May 18, 1917. These two disturbances together with the two Omachi earthquakes under consideration indicate the seismic activity manifested from different points of the Hime-kawa and Tenryu-gawa zone.

19. **SOUND AREA.** (Fig. 14.) It was quite characteristic of the Omachi earthquakes of 1918 that their numerous after-shocks were always accompanied with marked *meido*, or earth-sound like that caused by a heavy weight falling on the ground or like a distant booming of gun discharge, when perceived in the valleys of the Nogu-gawa and the Takase-gawa, namely, at the village localities of Matsuzaki and Jokoji (Yashiro-mra), Ippongi, Shimizu and Osaki (Tokiwa-mra), and northwards at Mori and Inao around the lake of Kizaki. It was found out, however, that the earth-sounds could not be heard at several places on the hilly region forming the eastern boundary of the above-mentioned plain of Omachi. Thus at the Kirikbo (Yasaka-mra), only the strongest after-shocks were accompanied by a feeble rushing sound like that of wind blowing, but none was accompanied by a *meido*. Likewise no *meido* was heard at Chishanota, Tabata, Soyama, and other districts lying to the north of the last mentioned place. Going westward from Soyama, the *meido* could be heard first at the Norikoe path on the southern flank of the mount Reishoji. Northwards from Soyama no *meido* could be heard even at Ohshio ; neither was it perceptible at Shingyo (Mima-mra) 6 km. to the N.W. from the latter. At Tera, however, midway between these two places, the *meido* could be distinctly heard. Thus, in the case of the present Omachi earthquakes, the area of the sound perception was clearly demarked from that of the non-perception ; the boundary, as shown in fig. 14, coinciding on the whole with the line separating the diluvial formation of the western edge of the hilly segion at the eastern limit of the Omachi plane and the Tertiary formation adjacent on the eastern side. To explain this phenomenon, it is to be remembered that the seismic *meido*, unlike the detonation of a volcanic outburst made up of sound waves of air, is composed of the minute vibrations of the ground sufficiently quick to be audible to human ears. Now the after-shocks

Fig. 13. Diagrammatic Section representing the Geological Formation of the District about Omachi.

S......Eastern Boundary Line of the Sound Area.



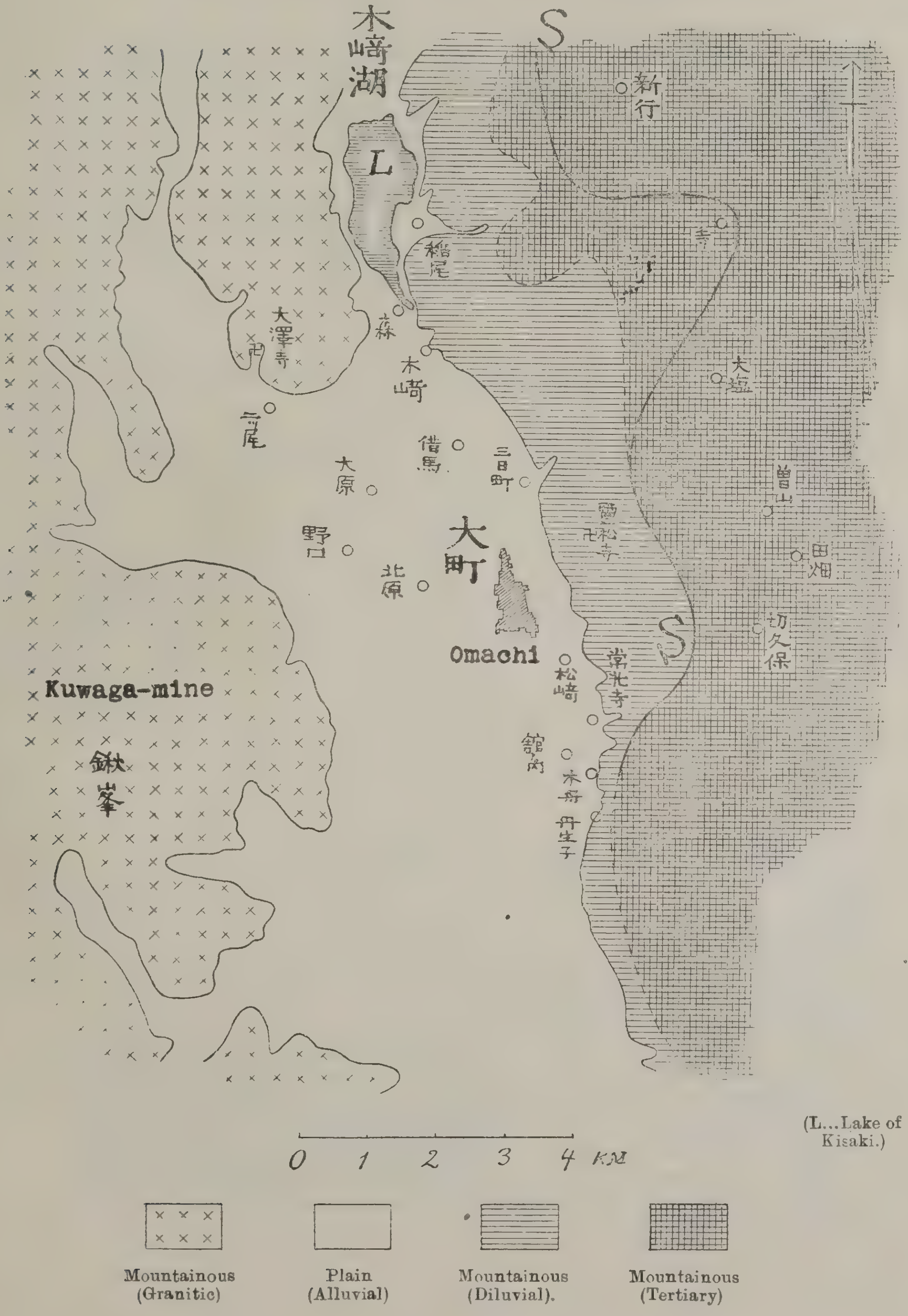
O......Omachi Plain. G......Granitic Mountain on the West.
D, T...Respectively the Diluvial and the Tertiary Hills on the East.
C......Principal Centre of the After-shocks.

under consideration had their main centre at about 4 km. to the S.W. of Omachi (C in fig. 13). As the focal depth was shallow, the minute earth vibrations were propagated into, and caused the *meido* on, the diluvial hills on the east side. These were, however, prevented from penetrating sufficiently into the comparatively hard Tertiary formation, resulting in the absence of the *meido* on the region further eastward. Had the seismic origin existed among the Tertiary mountains on the east side, the *meido* would naturally have been percieved strongly there.

20. **AFTER-SHOCK FREQUENCY.** Table V give the hourly frequency of the after-shocks of the destructive earthquakes on Nov. 11, 1918, registered with a tromometer at the meteorological observatory of Nagano. As the latter place is distant 35 and 39 km. respectively from the centres of the two destructive earthquakes, the list in the table does not contain very small ones among the after-shocks. Still the seismic frequency at Nagano on Nov. 11 amounted to 190 ; the daily numbers for the two next days being respectively 69 and 50. (See Table IV.) The frequency quickly decreased and was reduced to about 10 or less, totalling to 416 in the course of the 20 days between the 11th and the 30th of the same month. The daily frequency for Omachi, given in Tables IV and V, are based on the reports from the Omachi police station, dating from Nov. 15, which were limited to the sensible shocks and do not include the cases of mere earth-sounds. Yet the daily frequency between the 15th and the 18th (Nov.) was from 25 to 35, aggregating to 112. The total earthquake number tromometrically registered at Nagano during the same 4 days was only 35, or less than 1/3 of that for Omachi. Thus it is

Fig. 14. Map showing the Area of Audibility of Seismic Sounds in the vicinity of Omachi in the days following the Two Destructive Earthquakes on Nov. 11, 1918.

SS......The Demarkation Line to the west of which the Sounds were head, but to the east of which the Sounds were not perceptible.



(L...Lake of Kisaki.)

probable that the number of the sensible shocks and *meido* at the latter place was over 600 or 700 on Nov. 11, and over 300 or 400 on the next day.

The strong after-shocks clearly registered on the tromometer at the Seismological Institute in Tokyo are indicated in Table III.

Table III. List of the Strong After-shocks.

No.	Date.	Tokyo Observation.	
		Time of Occurrence.	Maximum Motion.
A	**1918** Nov. 11.	2^{h} 58^{m} 45^{s}A.M.	mm 3.3 .... 1st Destructive Eqke.
1	,,	3 16 45 ,,	0.92
B	,,	4 03 40 P.M.	11.8 .... 2nd Destructive Eqke.
2	Nov. 12.	0 02 26 A.M.	0.23
3	,,	3 34 23 P.M.	0.007
4	,,	10 57 31 ,,	0.068
5	Nov. 13.	0 00 46 A.M.	0.006
6	,,	3 53 42 ,,	0.070
7	,,	11 45 04 ,,	0.071
8	,,	11 52 42 ,,	0.012
9	Nov. 14.	0 57 41 ,,	0.014
10	Nov. 20.	9 48 55 ,,	0.020
11	Nov. 25.	4 56 55 ,,	0.200
12	Nov. 26.	4 05 58 P.M.	0.052
13	,,	5 38 56 ,,	0.113
14	,,	10 44 59 ,,	0.012
15	Dec. 1.	4 11 31 A.M.	0.019
16	Dec. 14.	5 34 43 P.M.	0.240
17	Dec. 21.	7 42 00 ,,	0.280
18	**1919** Jan. 21.	6 15 00 ,,	At Omachi, this was felt pretty severely and resulted in damage to porcelain, some people trying to run out of doors. In Tokyo the pulsatory oscillations which existed at the time confused the record. Yet it is clear that this shock was not so large as Nos. (2), (11), (16), and (17). The origin was probably right under the town of Omachi.

According to the Table III, excepting (1) which succeeded immediately the 1st destructive earthquake (A), the strongest after-shock was (17) which happened on Dec. 21st, namely, 40 days after the commencement. The three previous shocks (2), (11), and (16), were somewhat smaller. All these different disturbances, though not destructive, were fairly strong at Omachi and the vicinity. The occurrence of the predominant after-shocks is probably due to the general stress accumulation in the region to the S.W. of the meizoseismal area of the Zenkoji (1847) earthquake, the neighbourhood of the epifocus of a great destructive earthquake becoming frequently the seat of small local destructive shocks.

21. FREQUENCY FLUCTUATION OF AFTER-SHOCKS. From fig. 19, based on Table V, it will be seen that the daily frequency of the after-shocks observed at Nagano and Omachi was rather greater with high barometric pressure. Again, from fig. 17, which illustrates the course of fluctuation in the hourly seismic frequency observed at Nagano on Nov. 11th and 12th, it will be noted that the after-shocks of the destructive earthquake on the 11th, at 3 A.M., reached the maximum already between 7 and 11 o'clock in the same morning; the subsequent increase in the frequency being evidently preparately to the 2nd destructive earthquake at 4 P. M. on the same day. The number of the after-shocks which took place during the 7 hours subsequently to the occurrence of the 2nd destructive earthquake was 105, while that for the 1st destructive earthquake during the equal time interval was 57. These two numbers are in the ratio of 2 : 1 nearly.

Fig. 18 shows the quick rate of decrease in the daily frequency of the after-shocks observed at Nagano.

22. DIURNAL FREQUENCY VARIATION. Figs. 15 and 16, based on Tables III and IV, illustrate the diurnal frequency variation of the after-shocks at Nagano and Omachi respectively. The list of the shocks prepared by the Omachi Police Station, not being the result of an instrumental observation, is to be regarded as not furnishing proper material for the study under consideration. The instrumental observation at Nagano made subsequent to Nov. 12, 1918, indicates the principal frequency minimum between 2 and 3 P.M. and another between 2 and 3 A.M. It was just at these minimum frequency hours of the day, that the two destructive earthquakes took place. According to the tromometer observation in Tokyo, the 18 strong after-shocks registered there indicate a diurnal frequency variation similar to that for Nagano, being more numerous about noon, midnight, 4 A.M., and 5 P.M., as follows :

Hour.	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12
A.M.	3	0	0	2	2	0	0	0	0	1	0	2
P.M.	0	0	0	1	1	2	1	1	0	0	2	0

Diurnal Variation of the Frequency (=y) of the Omachi After-shocks.

Fig. 15.

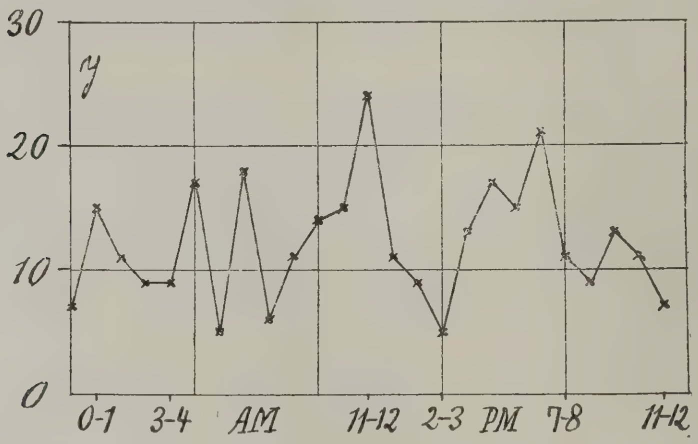


Fig. 16.

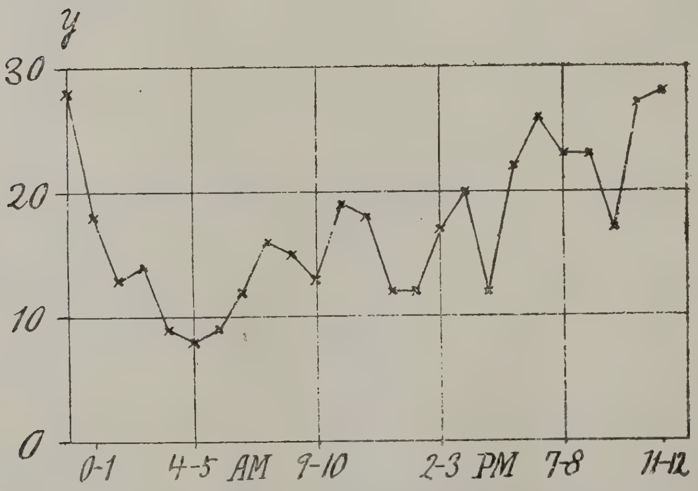


Fig. 15. Earthquakes instrumentally registered at the Nagano Meteorological Observatory.

Fig. 16. Sensible Earthquakes observed at Omachi Police Station.

Table IV. Diurnal Distribution of the Omachi After-shocks.

Hour.	Earthquakes instrumentally registered at Nagano Meteor. Observatory.*		Sensible Eqkes observed at Omachi Police Station, Nov. 15, 1918 to Jan. 24, 1919.
	Nov. 11, 1918.	Nov. 12, 1918 to Feb. 28, 1919.	
0 — 1 A.M.		15	18
1 — 2		11	13
2 — 3	1	9	14
3 — 4	29	9	9
4 — 5	14	17	8
5 — 6	2	5	9
6 — 7	4	18	12
7 — 8	1	6	16
8 — 9	6	11	15
9 —10	1	14	13
10 —11	1	15	19
11 —12	5	24	18
0 — 1 P.M.	6	11	12
1 — 2	1	9	12
2 — 3	1	5	17
3 — 4	7	13	20
4 — 5	29	17	12
5 — 6	29	15	22
6 — 7	14	21	26
7 — 8	9	11	23
8 — 9	9	9	23
9 —10	7	13	17
10 —11	7	11	27
11 —12	7	7	28
Total	190	296	403

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* The frequency given in this table is the result of a careful re-examination of the original Nagano tromometer diagrams, and is in some instances higher than that reported by the Nagano meteorological observatory.

Table V. Mean Daily Barometric Pressure at Matsumoto compared with Daily Frequency of the Sensible Earthquakes observed at the Police Station of Omachi and of the Earthquakes registered instrumentally at the Meteorological Observatory of Nagano. Nov. 1918–Feb. 1919.

Day.	Barometric Pressure at Matsumoto. 700 mm +				Sensible Earthquakes at Omachi.			Eqkes instrumentally registered at Nagano.*			
	1918 XI	1918 XII	1919 I	1919 II	1918 XI	1918 XII	1919 I	1918 XI	1918 XII	1919 I	1919 II
1	20.2	16.9	8.6	15.3		6			2	2	0
2	16.7	15.3	5.0	16.5		7	2		1	2	0
3	12.2	15.9	7.9	13.0		4	2		3	2	0
4	17.1	15.4	9.4	6.0		6	2		2	3	1
5	13.3	14.3	11.5	14.5		3	1		1	1	0
6	6.0	14.5	16.1	20.8		11	1		3	1	0
7	10.1	10.3	18.2	17.5		3			2	0	0
8	12.8	8.5	18.2	14.1		1			0	0	0
9	13.7	11.9	12.8	15.5		4			3	2	1
10	9.3	15.5	13.7	7.5		1			0	2	2
11	14.1	9.2	11.0	8.7		1	1	118	1	0	0
12	20.5	4.3	4.4	14.5		9	1	69	2	0	0
13	24.1	9.6	4.7	19.8		3		50	2	0	1
14	12.8	5.3	11.2	9.1		6		12	11	1	0
15	13.3	8.6	11.8	14.8	25	5	3	14	2	1	0
16	17.8	14.5	13.3	16.7	27	0		12	0	0	0
17	14.7	14.0	15.7	12.9	35	0	2	4	0	1	0
18	9.2	16.5	16.3	10.0	25	1		7	1	0	0
19	9.7	17.7	5.3	5.6	17	2		1	0	0	1
20	14.4	12.5	3.0	11.1	15	1		8	0	1	0
21	16.4	17.2	4.3	12.8	18	5	7	3	5	2	0
22	11.7	14.5	7.1	5.1	15	6	1	4	6	1	0
23	8.5	12.4	12.7	3.5	16	—	—	5	1	0	1
24	9.7	16.6	14.5	7.0	17	—	1	3	0	1	0
25	12.7	15.6	9.9	7.3	19	—	—	6	2	0	0
26	14.3	13.0	13.2	11.6	24	—	—	9	0	0	1
27	12.2	10.4	14.8	11.4	15	—	—	8	0	4	0
28	16.7	12.7	14.5	9.2	10	—	—	4	0	0	1
29	22.5	12.2	14.5		15	2	—	4	0	0	—
30	21.6	13.6	12.3		6	6	—	3	2	1	—
31		15.5	12.1		—	1	—	—	0	0	—
Total					310	83	24	344	52	28	9

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* The frequency is the daily number of earthquakes reported by the Nagano Meteorological Observatory.

Table VI. Hourly Frequency of the Earthquakes instrumentally registered at the Meteorological Observatory of Nagano. Nov. 11–30, 1918.

Day. / Hour.	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
A.M.																				
0 — 1	—	8	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0
1 — 2	—	4	0	1	2	1	0	2	0	0	0	0	0	0	0	0	0	0	1	0
2 — 3	1	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 — 4	30	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
4 — 5	14	1	5	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0
5 — 6	2	2	1	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0
6 — 7	4	1	1	2	5	0	0	0	0	2	0	0	1	0	0	0	2	0	0	1
7 — 8	1	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
8 — 9	6	2	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	1	0
9 —10	1	2	4	0	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	1
10 —11	1	4	4	0	0	0	2	0	0	1	0	0	1	0	0	2	0	0	0	0
11 —12	5	4	9	0	0	0	1	3	0	0	0	1	0	0	1	0	0	1	0	0
P.M.																				
0 — 1	6	1	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 — 2	1	0	5	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2 — 3	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 — 4	7	1	0	0	1	2	0	0	0	0	0	0	0	1	0	0	0	0	1	0
4 — 5	30	5	2	2	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
5 — 6	29	1	2	0	2	0	0	0	0	1	0	1	0	0	0	2	1	0	1	0
6 — 7	14	7	2	0	0	2	0	0	0	0	0	0	1	0	1	0	1	0	0	0
7 — 8	9	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
8 — 9	9	2	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9 —10	7	3	1	1	0	0	0	0	0	0	0	0	0	0	2	1	2	1	0	0
10 —11	7	4	1	1	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0
11 —12	7	2	2	1	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0

Table VII. Hourly Frequency of the Sensible Earthquakes observed at the Police Station of Omachi. Nov. 11–30, 1918.

Hour. \ Day.	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
A.M.																				
0 — 1	—	3	—	—	3	0	1	2	2	1	0	0	1	0	0	3	1	0	0	0
1 — 2	—	5	—	—	2	0	0	1	2	0	0	0	0	4	0	0	0	0	1	0
2 — 3	—	3	—	—	0	0	0	2	2	1	1	0	3	1	0	0	0	0	1	0
3 — 4	—	—	—	—	0	1	0	0	1	0	1	0	1	0	0	0	1	0	2	0
4 — 5	—	—	—	—	0	0	0	1	1	0	0	0	0	0	2	0	0	2	0	1
5 — 6	—	—	—	—	0	3	1	0	0	0	1	0	0	0	0	1	0	0	1	0
6 — 7	—	—	—	—	1	0	0	0	1	0	1	0	1	0	3	0	2	0	1	1
7 — 8	—	—	—	—	2	1	0	1	0	0	0	0	0	4	2	0	0	1	1	1
8 — 9	—	—	—	—	2	0	0	1	0	1	2	1	0	1	0	0	0	1	1	0
9 —10	—	—	—	—	2	1	0	1	0	1	0	0	0	0	1	0	0	0	0	1
10 —11	—	—	—	—	2	1	1	0	1	1	2	3	0	0	1	2	1	0	1	0
11 —12	—	—	20	—	0	0	1	4	0	0	0	3	0	0	2	0	0	1	0	0
P.M.																				
0 — 1	—	—	—	—	2	0	2	0	1	2	1	0	1	0	1	0	0	0	0	0
1 — 2	—	—	—	1	0	1	0	1	3	1	0	1	0	0	0	1	1	0	0	0
2 — 3	—	—	15	0	2	0	2	1	0	2	0	1	1	2	0	0	0	2	0	0
3 — 4	—	—	—	0	3	1	2	2	0	0	0	2	1	3	0	0	0	0	0	0
4 — 5	—	24	—	3	0	2	1	0	0	0	1	0	0	0	0	2	0	0	1	0
5 — 6	—	—	—	0	0	0	6	0	0	1	1	1	1	0	0	4	1	0	1	0
6 — 7	39	—	—	0	2	2	4	0	0	0	0	1	1	0	1	4	1	1	2	0
7 — 8	48	—	—	1	1	2	1	0	1	1	3	0	0	0	1	2	1	1	0	1
8 — 9	—	48	—	0	0	5	4	0	0	1	0	1	1	1	0	2	0	0	1	0
9 —10	—	1	—	2	0	4	0	0	0	0	0	0	0	0	2	1	2	1	0	0
10 —11	—	30	—	3	0	1	0	4	0	1	2	1	1	0	1	1	2	0	1	1
11 —12	—	—	—	3	1	2	9	4	2	1	2	0	3	1	2	1	2	0	0	0

Fig. 17. Variation in the Hourly Frequency (=y) of the Omachi After-shocks registered instrumentally at the Meteorological Observatory of Nagano.

Nov. 11–13, 1918.

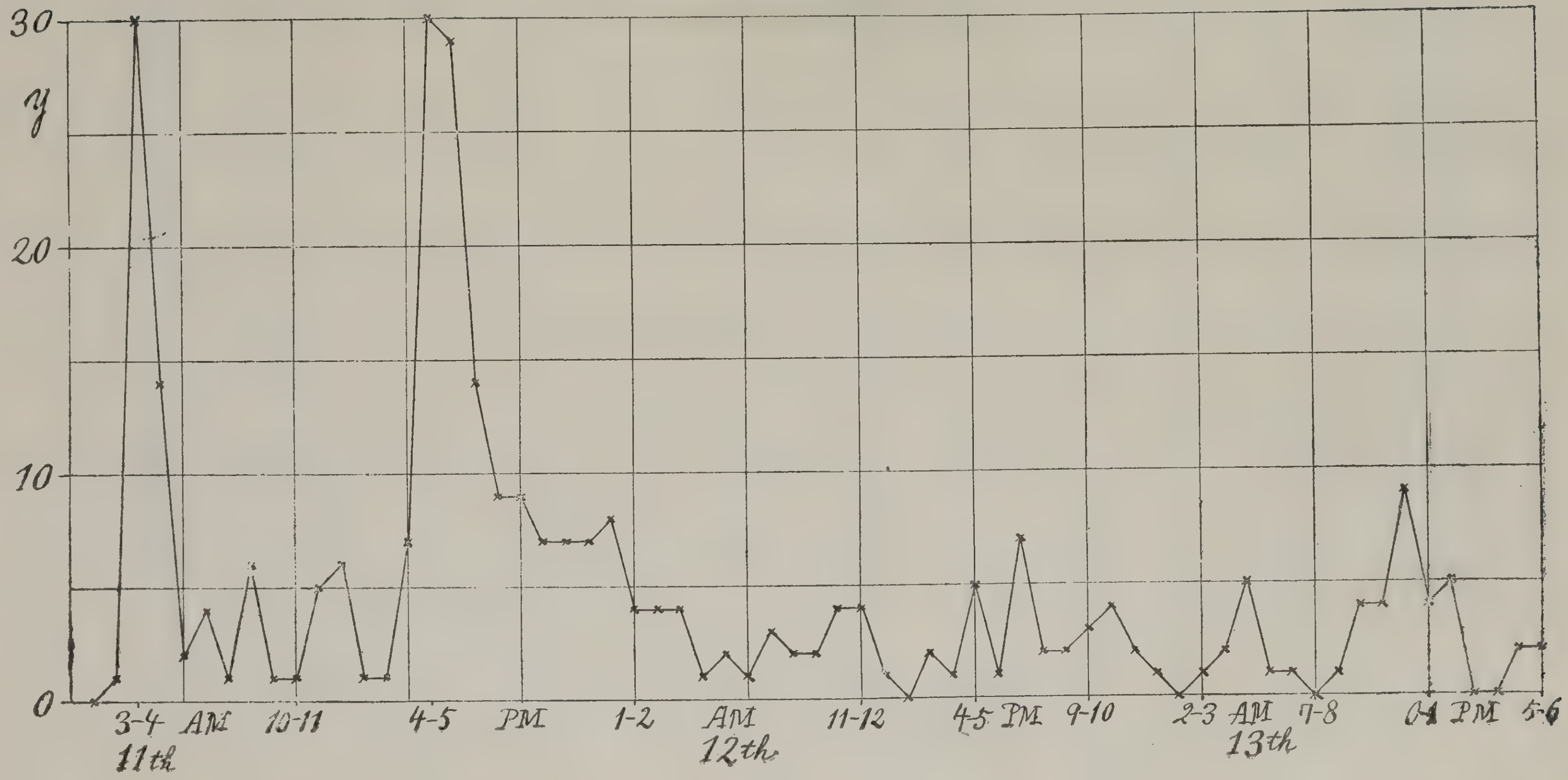
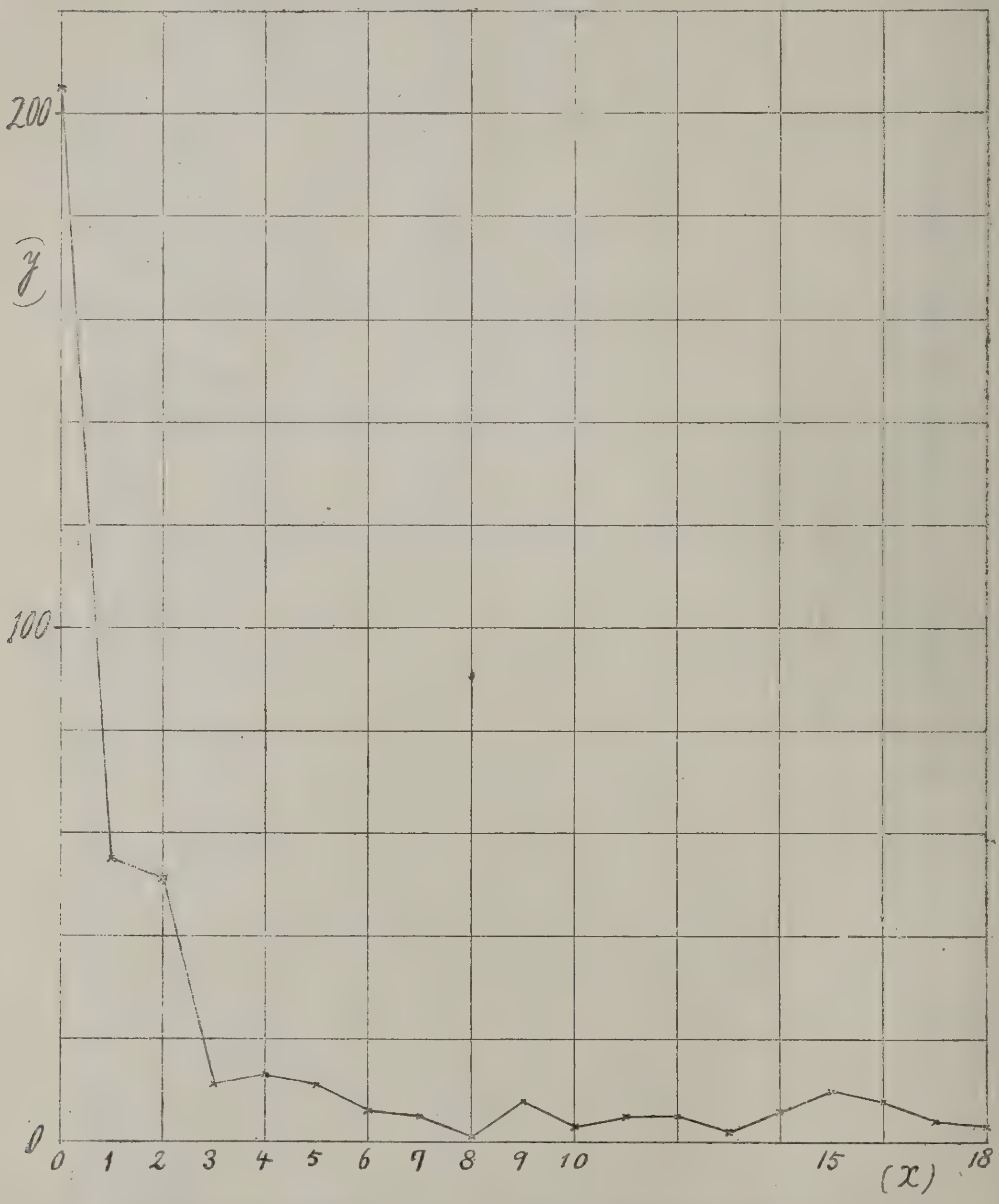


Fig. 18. 24-Hour Frequency Variation of the Omachi After-shocks registered instrumentally at the Meteorological Observatory of Nagano.

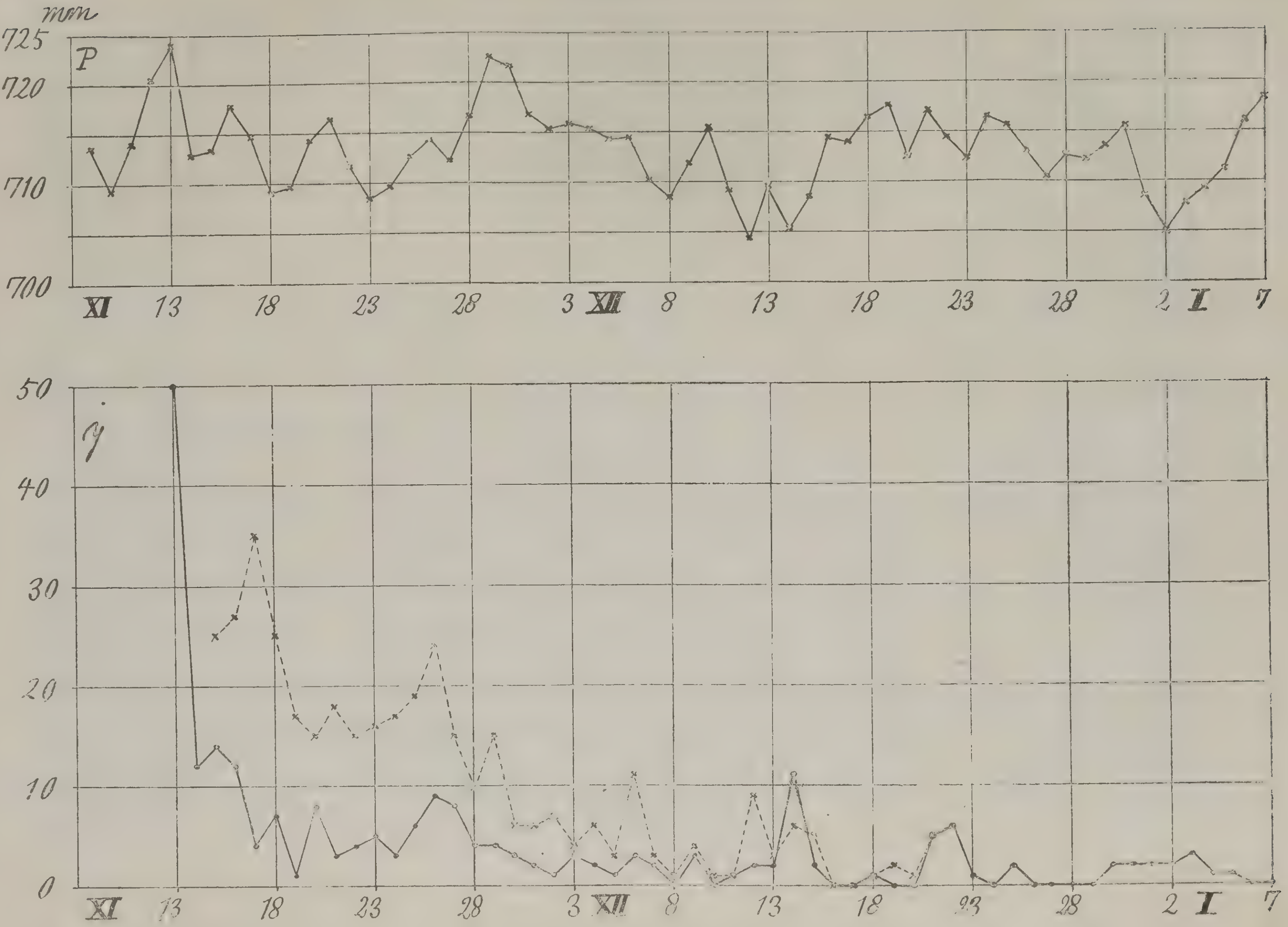


X=Time in unit of 24 hours. y=Seismic Frequency corresponding to x.

x=0......corresponds to 11th, 3 A.M.-12th, 3 A.M., Nov. 1918.

Fig. 19. Daily Seismic Frequency (=y) at Nagano and Omachi compared with Mean Barometric Pressure (=P) at Matsumoto.

Nov. 9, 1918–Jan. 7, 1919.



Dotted and full broken lines refer respectively to Omachi and Nagano Fuko Frequencies.

23. ORIGIN OF THE AFTER-SHOCKS AND MEIDO. During my stay at the Omachi districts, Nov. 14 to 20, and Nov. 28 to Dec. 5, 1918, I have perceived 155 after-shocks whose daily frequency was as follows :—

Date.	Number of shocks.	Date.	Number of shocks.
Nov. 14th	15 (after 1 P.M.)	Dec. 1st	2
15th	32	2nd	6
16th	30	3rd	3
17th	24	4th	4
18th	18	5th	1 (till 6 A.M.)
19th	13		
20th	7		

The sensible after-shocks were very sharp in nature. Each began with an earth-sound or " meido," *dōn* or *tōn* like the noise caused by the fall of a heavy body on the ground, or *dodo*......like the peal of a distant thunder, followed immediately after by quick vertical earthquake tremors apparently emanating from under the feet of the observer ; the accompaniment of the horizontal component being often insignificant. The time interval between the initial earth-sound and the principal movement, or the duration of the preliminary tremor, was judged to be mostly from 0.5 to 1.0 sec. The duration of the sensible earthquake motion was also short, varying mostly from 1 to 3 sec., as follows :—

Duration of sensible motion.	Number of cases.	Duration of sensible motion.	Number of cases.
under 1 sec.	6	5 sec.	5
1 sec.	17	6 ,,	2
2 ,,	13	7 ,,	2
3 ,,	17	10 ,,	2
4 ,,	3		

At Omachi, the *meido* were most frequently heard toward the S.W. At Matsuzaki, Jokoji and other places on the hilly districts to the east of the Omachi plain, these were heard toward the S.W. or the N.W.; in the neighbourhood of the lake of Kizaki in the north, toward the S. or the S.S.W.; in the vicinity of Ippongi in the south, toward the N.W.; at Nagahata, Osaki, Nakahara, and other places in the hilly districts to the west of the Omachi plane, toward the S., S.E., or N.N.W. The direction observation may be summarized as follows :—

Omachi	Mostly S.W.
Immediately to the south of Omachi	S.60°W.; W.N.W.; W.S.W.
Vicinity of Takase Bridge	N.; N.W.
Ippongi	N.W.
E. shore of Lake Kizaki (夏期大學)	S.15°W.; S.15°W.
S. end of Lake Kizaki (仁科紀念碑附近)	S.
Ozasa	N to S.
Hirako (一ノ宮)	N.E.; N.E.; S.30°W.; S.60°W.
Matsuzaki	S.60°W.; S.40°W.; S.W.; N20°W.
Jokoji	N.W.; N.40°W.
Nagahata	S.S.E.
Osaki	S.10°E.
Nagahara	N.; N.W.
Ohara	N.70°W.

The principal origin of the after-shocks and *meido* were located in the region lying to the S.W. of the town of Omachi, and did not necessarilly coincide with the centres of the two destructive disturbances themselves ; it being generally true that after-shocks occur most abundantly in the immediate neighbourhood of the epifocus of a great earthquake.

24. TROMOMETER OBSERVATION AT OMACHI. Temporary seismographical observation of the after-shocks was made during the 9 days between Nov. 27th and Dec. 25th, 1918 by means of a portable horizontal pendulum tremor-recorder set up on the concrete floor of the Coronation Memorial Hall in the compound of the Kita-Atsumi District Office, in Omachi. The observation work was carried on by Mr. Y. Takahashi, mechanic of the Seismological Institute, and Mr. J. Nishizawa, director, and Mr. M. Kawazoe, observer, of the Nagano meteorological observatory.

The result of the observation is summarized in Table VIII, from which it will be seen that the duration of the preliminary tremor was sometimes absolutely zero, but in many cases it was about 1 sec., signifying that the distances of the after-shock origins from the town of Omachi varied mostly from 3 to 7 km., with the mean of 5.0 km. The very first displacement of the preliminary tremor was generally directed toward the N.E. or N.N.E., which fact, combined with the observations relating to the after-shocks and the *meido*, indicates that these latter originated at places about 5 km, principally to the S.W. or W.S.W. of Omachi.

Table VIII. Summary of the Tromometer Observations at Omachi.

R = Distance between Omachi and Eqke Origin.
Max. 2a = Maximum Motion.

Time of Occurrence.	Duration of Preliminary Tremor.		R	Max. 2a		1st Displacement of Prel. Tremor.	1st Displacement of Principal Portion.	Duration of	
	E.W.	N.S.		E.W.	N.S.			Princ. Port.	Total Eqke.
29, Nov.									
	sec.	sec.	km.	mm.	mm.	mm.			
9.30 A.M.	0.9	0.9	5.4	0.066	0.045	0.012 → N70°E	——	—	—
11.45 ,,	—	1.1	6.9	0.044	0.034	——	——	—	—
5.58 P.M.	0?	0?	0?	0.013	0.022	——	mm. 0.017 → S36°E	—	—
6.30 ,,	1.0	1.0	6.0	0.044	0.040	→ N45°E	0.030 → S45°E	—	—
30, Nov.									
6.57 A.M.	1.3	1.3	8.6	0.017	0.025	0.005 → N72°E	0.020 → N43°E	sec. 2.0	—
7.30 ,,	1.0	0.9	5.4	0.047	0.034	0.007 → N73°E	0.020 → N45°W	—	sec. 4.0
9.48 ,,	0.6	0.94	3.6	0.058	0.047	——	——	2.7	—
11.45 ,,	0	0	0	0.038	0.034	0.016 → N45°W	——	1.0	—
1, Dec.									
4.10 A.M.	—	0.77	4.6	—	—	0.149 → N75°W	——	—	—
5.00 ,,	0.96	0.70	4.2	0.15	0.13	0.006 → N59°E	——	0.7	—
0.15 P.M.	0.93	0.93	5.6	0.055	0.034	0.004 → N14°W	0.026 → S71°E	2.3	—
6.35 ,,	1.00	1.00	6.0	0.15	0.13	0.010 → N24°W	——	—	—
2, Dec.									
2.48 A.M.	0.53	0.53	3.2	0.13	0.12	0.015 → S71°E	0.156 → N46°W	3.0	9.0
3.00 ,,	0.80	—	4.8	0.051	0.051	0.012 → E	——	1.1	2.5
4.15 ,,	1.00	0.90	5.4	0.035	0.032	0.014 → N69°E	——	—	—
10.38 ,,	—	0.96	5.8	0.035	0.015	——	——	0.6	—
4.00 P.M.	1.10	1.10	6.9	0.015	0.006	0.010 → N82°E	0.015 → N71°E	0.3	—
7.00 ,,	1.40	0.80	4.8	0.020	0.013	0.003 → N39°E	——	1.0	—
8.39 ,,	0.88	0.88	5.3	0.039	0.035	0.012 → N66°E	→ N45°E	2.0	—

Time of Occurrence.	Duration of Preliminary Tremor.		R	Max. 2a		1st Displacement of Prel. Tremor.	1st Displacement of Principal Portion.	Duration of	
	E.W.	N.S.		E.W.	N.S.			Princ. Port.	Total Eqke.
3, Dec.									
	sec.	sec.	km.	mm.	mm.	mm.	mm.	sec.	sec.
7.23 A.M.	1.10	—	6.9	0.085	0.082	0.016→N72°E	0.099→N66°E	1.6	3.5
7.41 ,,	0.31	0.52	3.1	0.272	0.155	0.012→N26°E	----	3.1	11.0
4, Dec.									
3.13 P.M.	1.37	1.37	9.0	0.155	0.260	0.020→N41°W	0.178→S29°W	5.5	8.0

25. LEVELING SURVEY BETWEEN MATSUMOTO AND ITOIGAWA. It is well known that the great Mino-Owari earthquake of 1891, the Usu-san eruption in 1910, and the Sakura-jima eruption in 1914 were accompanied by remarkable vertical and horizontal displacements of the ground. In the province of Shinano, noted for its volcanic and seismic disturbances, there were within comparatively recent times the eruptions of the Asama-yama and the Yake-dake and the great seismic catastrophe of Zenkoji (1847). It seemed likely that the present Omachi earthquakes, which occurred in the valley skirting the eastern base of the heavy mountain range of the Japan Alps, might possibly have been accompanied by vertical and horizontal disturbances in the earth's crust of the focal region. As a part of the investigation in this connection there has been instituted, through the liberality of the Imperial Academy, the height revision of the 56 bench marks for the distance of 111.7 km., beginning with B.M. No. 2873 in the city of Matsumoto in the south, thence proceeding northward and reaching B.M. No. 2928 in the town of Itoigawa on the coast of the Japan sea ; the survey work having been finished in the course of 81 days between June 20 and Sept. 9, 1920. The southern portion of the line of the precise leveling is laid through the plane ground, for the distance of 40 km. from Matsumoto to the north of Omachi. Thence the valley narrows and there is formed for the distance of 8 km. a series of three high elevation lakes of Kizaki, Nakatsuna, and Aoki. The Sano-saka at the northern flank of the last named lake forms the water-shed, thence the valley of the Hime-kawa leading northward to Itoigawa. (See fig. 20.)

I must here state my obligations to Major-General H. Matsumra, Director, Colonel R. Terae, Chief of Triangulation Bureau, and Mr. Y. Hiraki, surveyor, of the Military Survey, who accorded me various kind assistances in this as well as in several former occasions connected with the examination of the topographical changes caused by the seismic and volcanic disturbances. My special thanks are due to Mr. Yoshitoki Ogata, assistant surveyor in the same department, who has carried on the actual leveling survey work.

Notes on the bench marks. The bench marks between Matsumoto and Itoigawa were first set in the years 1891 to 1893, with the exception of Nos. 2906 and 2908, as follows :—

B.M. 2873 (Matsumoto)	set in 1893.	B.M. 2908	reset in 1906.
2874–2895	,, 1891.	2909–2910	reexamined in 1906.
2896–2905	,, 1892.	2911–2913	set in 1892.
2906	reset in 1906.	2916–2927	,, ,,
2907	set in 1892.	2928 (Itoigawa)	,, 1893.

Of the different bench marks, Nos. 2906, 2919–2921, and 2912–2916 had been swept away by floods or buried in soil, while nineteen others suffered some inclination or were slightly damaged, as follows :—

List of the Damaged Bench Marks.* (Notes by Mr. Y. Ogata.)

B.M.	Damaged Condition.	Remark.
2873	Buried 0′.6 under ground.	In city ground ; buried in consequence of the filling up of the road. The vicinity had originally been a puddy field.
2874	Slightly inclined toward the eastern side, where there is a ditch 4′ deep.	In city of Matsumoto ; on the side of a road, with a telegraph post at the distance of 2 feet.
2875	The top of the B.M. stone damaged by fire.	
2879	Exposed 1′.8, with the top spherical portion broken 8 mm.	In the town of Toyoshina. The locality of the B.M., originally a mulberry field, has since been converted into town streets.
2880	Inclined 4°.	Situated only 2′ distant from a manure reservoir.

B.M.	Damaged Condition.	Remark.
2881	About 3 cm. uplifted, with a slight inclination.	Probably removed by subsequent road and ditch makings.
2883	Inclined about 11°.	Situated at the eastern side of a road, with a fish pond a few feet further eastwards.
2885	„ 5°.	On a road with puddy fields on both sides.
2886	Inclined about 8°; top portion 4 mm. broken.	
2888	Inclined about 10°; top portion 4 mm. broken.	On a road with houses on both side.
2892	Exposed 1′.8 above the ground.	In the town of Omachi, the road having an inclination in E.W. direction. Due probably to the denudation of the soil.
2893	Inclined about 10°.	On road with puddy fields and ditches on both sides.
2903	Inclined about 8°, with an exposure of 1′.8 above the ground.	On a road, with puddy fields on both sides, 4′ lower in level.
2905	*Do.*	„
2906	Carried away by flood.	
2910	Top portion 4 mm. broken off.	On road, with a mountain slope on the south and overlooking a river on the north; due probably to the falling down of sand and earth.
2911	Buried 0′.6 deep in the ground.	
2918	Lost in consequence of new road making.	
2919–21	Buried in consequence of road making or carried away by flood.	
2922	Top spherical portion 4 mm. broken off.	
2927	Inclined about 20°.	On road, with puddy fields on both sides.

* The five B.M. Nos. 2912–2916, have been restituted in the course of the present survey. The damage done to the top of the B.M. stones was evidently due to the passage over them of the wagons in winter times when the depth of snow accumulation on the road became equal to their height.

26. RESULT OF THE LEVELING SURVEY. Table IX contains the results of the height determination of the bench marks along the line of precise leveling between Itoigawa and Matsumoto. If the B.M. No. 2873 in the latter city be assumed to be unchanged in height, then the B.M. No. 2891 in the town of Omachi had the maximum elevation of 189.6 mm., while the B.M. No. 2928 in the town of Itoigawa on the Japan sea coast must have suffered a depression of 199.3 mm. If, on the other hand, the bench mark at Itoigawa be assumed to have remained unchanged in height, then the ground level at Omachi must have been elevated 388.9 mm. (See fig. 22.) Whichever of these two hypotheses be true, it will be seen that in the south the 16 bench marks Nos. 2873–2888 indicated no marked mutual height changes between the old and the new leveling survey. On the other hand, in the north, on the Japan sea side, the 21 bench marks Nos. 2928 to 2908 indicated a regular continuous mutual height variation. In other words, the tract of 40 km. in length to the south of the town of Itoigawa suffered, a relative northward depression at an average rate of 4 mm. per km., while there was no special relative height change for the distance of 30 km. northwards from the city of Matsumoto. It is, however, remarkable that the central tract of 40 km. from the B.M. No. 2889 to B.M. No. 2907 indicated height disturbances distinct from that of either end portion. Thus, (i) the distance of about 14 km. from the B.M. No. 2889 to B.M. No. 2895 about the town of Omachi is an area of upheaval, the maximum elevation relative to the region adjacent to the south being about 19 cm. On the contrary, (ii) the B.M. Nos. 2896 to 2907, for the distance of 26 km., to the north of the above mentioned elevation area, suffered a depression to the maximum amount of 6.6 to 8.7 cm when referred to the tract of 30 km. to the north of Matsumoto. The contiguity of the (i) elevation and the (ii) depression areas must be the result of the co-related mutual compensation of the upward and the downward displacements of the neighbouring portions in the earth's crust. A similar relation was also found in the case of the great Mino-Owari earthquake of 1891 which was accompanied by the well-defined dislocations of the ground in the mountainous districts amounting to 18 feet both in the horizontal and the vertical direction. In the plain of Mino-Owari, a zone of tract to the east of the line connecting the cities of Nagoya and Gifu was elevated, with the depression rigions on both sides; indicating a maximum vertical disturbance of 1.19 m., of which 0.77 m. was elevation and 0.42 m. was depression. In the Omachi earthquakes, the total vertical displacement in the meizoseismal area was 0.2763 m., of which the elevation was greater than the depression, as was the case with the Mino-Owari earthquake.

Table IX. Precise Leveling between Matsumoto and Itoigawa: Comparison of the Heights before and after the Omachi Earthquakes of Nov. 11, 1918.

Bench Mark.	(I) Height in 1920.	(II) Height in 1891–3.	Height Difference (I –(II).	Correction due to an abnormal condition of B.M.	Corrected Height Difference.
	m	m	m.m	m.m	m.m
2873	588.4304	588.4304	0.0	0.0	0.0
2874	584.7293	584.7169	+ 12.4	+ 1.0(1)	+ 13.4
2875(†)	575.8983	575.7687	———	———	———
2876	589.6151	589.6040	+ 11.1	+ 1.0(2)	+ 12.1
2877	587.0829	587.0688	+ 14.1	+ 1.0(1)	+ 15.1
2878	576.1629	576.1583	+ 4.6	0.0	+ 4.6
2879	557.0517	557.0541	− 2.4	+ 8.0(2)	+ 5.6
2880	540.2268	540.2329	− 6.1	+ 8.0(1)	+ 1.9
2881	539.9017	539.8598	+ 41.9	+ 5.0(2)	+ 46.9
2882	535.2842	535.2847	− 0.5	+ 5.0(2)	+ 4.5
2883	542.3566	542.3634	− 6.8	+10.0(2)	+ 3.2
2884	557.8762	557.8799	− 3.7	0.0	− 3.7
2885	575.5190	575.5161	+ 2.9	+ 5.0(1)	+ 7.9
2886	597.7906	597.8004	− 9.8	+ 5.0(2)	− 4.8
2887	621.7172	621.7309	− 13.7	0.0	− 13.7
2888	647.9336	647.9518	− 18.2	+14.0(1)	− 4.2
2889	678.6073	678.5915	+ 15.8	0.0	+ 15.8
2890	704.3609	704.2015	+159.4	0.0	+159.4
2891	707.5931	707.4035	+189.6	0.0	+189.6
2892	729.8287	729.6832	+145.5	0.0	+145.5
2893	754.0815	754.0167	+ 64.8	+10.0(1)	+ 74.8
2894	765.3263	765.3114	+ 14.9	0.0	+ 14.9
2895	766.4261	766.4239	+ 2.2	0.0	+ 2.2
2896	789.7700	789.8430	− 73.1	0.0	− 73.1
2897	825.5150	825.6007	− 85.7	0.0	− 85.7
2898	823.4081	823.4859	− 77.8	0.0	− 77.8
2899	812.0371	812.1092	− 72.1	0.0	− 72.1
2900	746.7901	746.8737	− 83.6	0.0	− 83.6
2901	736.2585	736.3294	− 70.9	0.0	− 70.9
2902	722.9395	723.0055	− 66.0	0.0	− 66.0

Bench Mark.	(I) Height in 1920.	(II) Height in 1891-3.	Height Difference (I)-(II).	Correction due to an abnormal condition of B.M.	Corrected Height Difference.
	m	m	m.m	m.m	m.m
2903	711.4931	711.5878	− 94.7	+ 8.0(1)	− 86.7
2904	698.0724	698.1449	− 72.5	0.0	− 72.5
2905	664.6884	664.7772	− 88.8	+ 8.0(1)	− 80.8
2906(†)	613.9520	616.0314	———	———	———
2907	583.9508	584.0165	− 65.7	0.0	− 65.7
2908	549.5823	549.6156	− 33.3	0.0	− 33.3
2909	516.6509	516.6947	− 43.8	0.0	− 43.8
2910	482.1895	482.2619	− 72.4	+ 4.0(2)	− 68.4
2911	461.0680	461.1170	− 49.0	0.0	− 49.0
2912(*)	491.3754	442.9159	———	———	———
2913(*)	415.9726	400.2620	———	———	———
2914(*)	383.0582	371.6001	———	———	———
2915(*)	386.6180	145.7101	———	———	———
2916(*)	410.7305	317.8007	———	———	———
2917	263.1486	263.2496	−101.0	0.0	−101.0
2918	227.2336	227.3461	−112.5	0.0	−112.5
2919	201.6372	203.9560	———	———	———
2920	164.8008	158.4492	———	———	
2921	134.4600	130.2411			———
2922	108.4254	108.5718	−146.4	+ 4.0(2)	−142.4
2923	89.5664	89.7408	−174.4	0.0	−174.4
2924	71.6212	71.7922	−171.0	0.0	−171.0
2925	50.5236	50.6934	−169.8	0.0	−169.8
2926	31.8143	32.0064	−192.1	0.0	−192.1
2927	18.2487	18.4578	−209.1	+20.0(1)	−189.1
交叉點 2928	8.8839	9.0832	−199.3	0.0	−199.3

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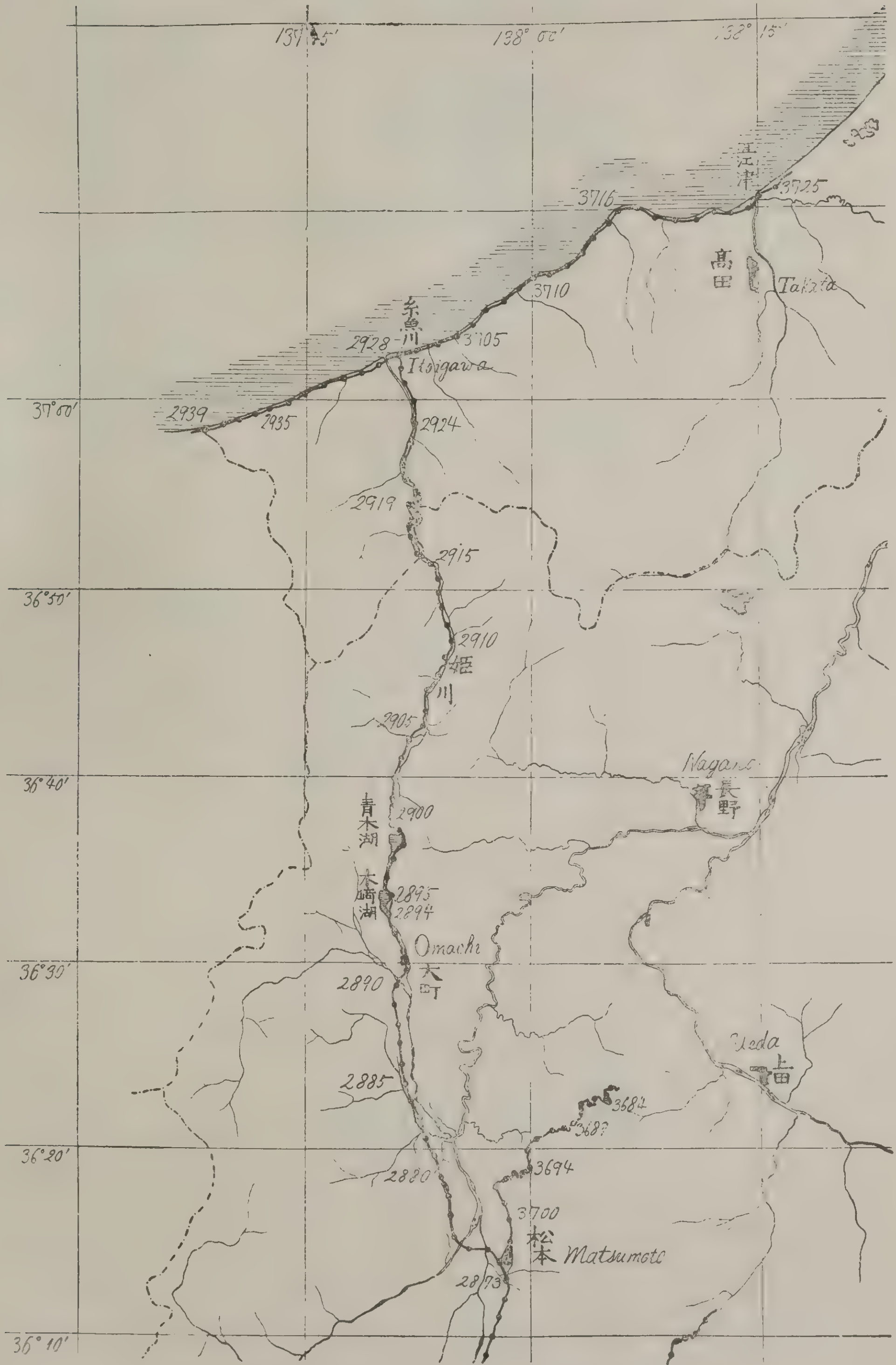
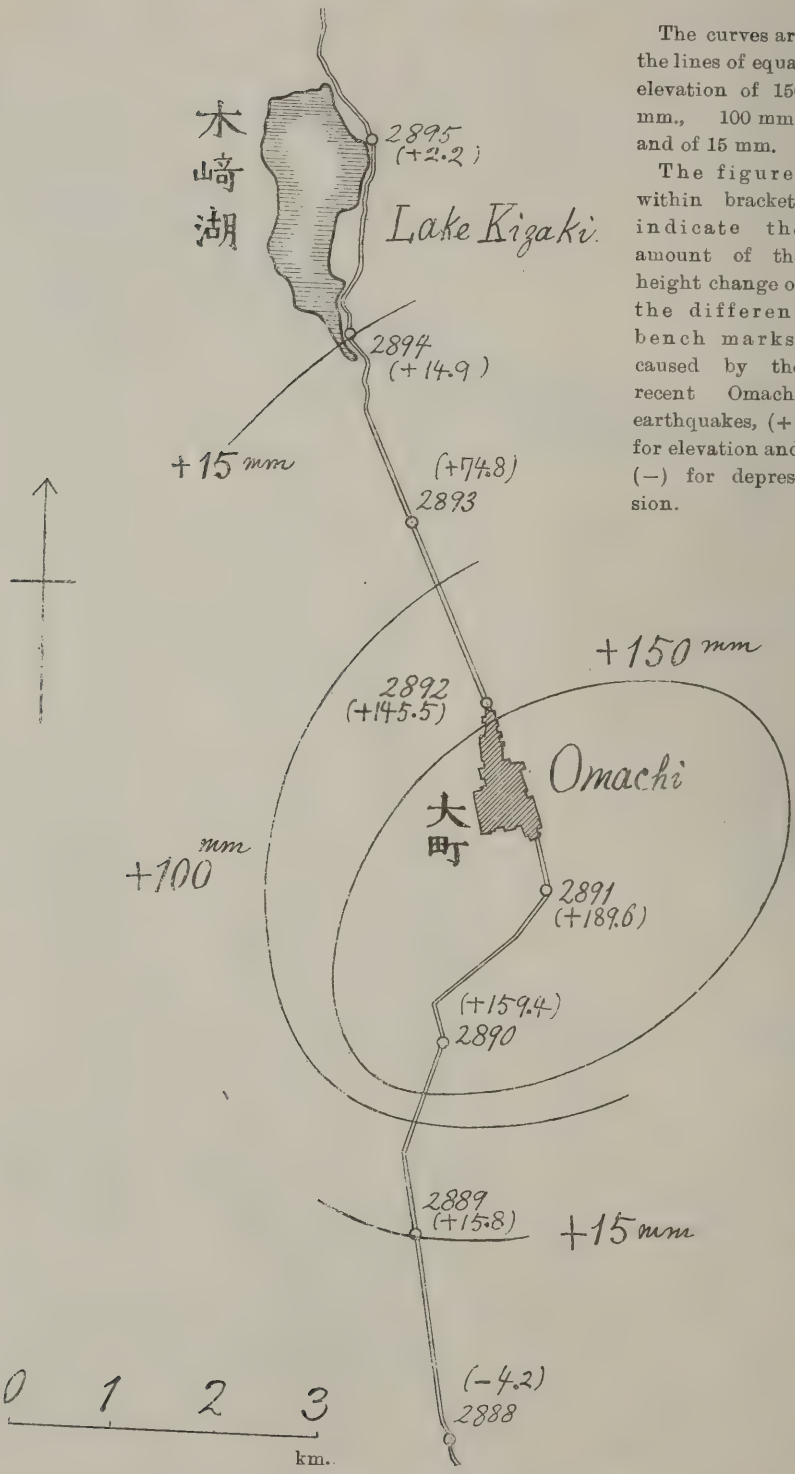
(1) Correction due to the inclination of the B.M. stone.
(2) ,, ,, a partial breaking of the top of the B.M. stone.
* B.M. newly set up in 1920.
† Provisionary B.M.

Fig. 20. Map showing the Precise Leveling Line between Matsumoto and Itoigawa and in the neighbouring regions.



The bench marks (•) are placed at intervals of 2 km.

Fig. 21. Map showing the Elevation of the Ground in the Epicentral Region of the Omachi Earthquakes of 1918.



The curves are the lines of equal elevation of 150 mm., 100 mm., and of 15 mm.

The figures within brackets indicate the amount of the height change of the different bench marks, caused by the recent Omachi earthquakes, (+) for elevation and (−) for depression.

Fig. 22. Difference in Heights of the Bench-Marks between Matsumoto and Itoigawa before and after the Destructive Omachi Earthquakes of 1918.

The upper figure indicates the height change (in mm.) of the different bench-marks relative to B.M. No. 2873 in Matsumoto, (+) for Elevation and (−) for Depression.

The lower figure gives the height (in metres) of the different B.M. between Matsumoto and Itoigawa.

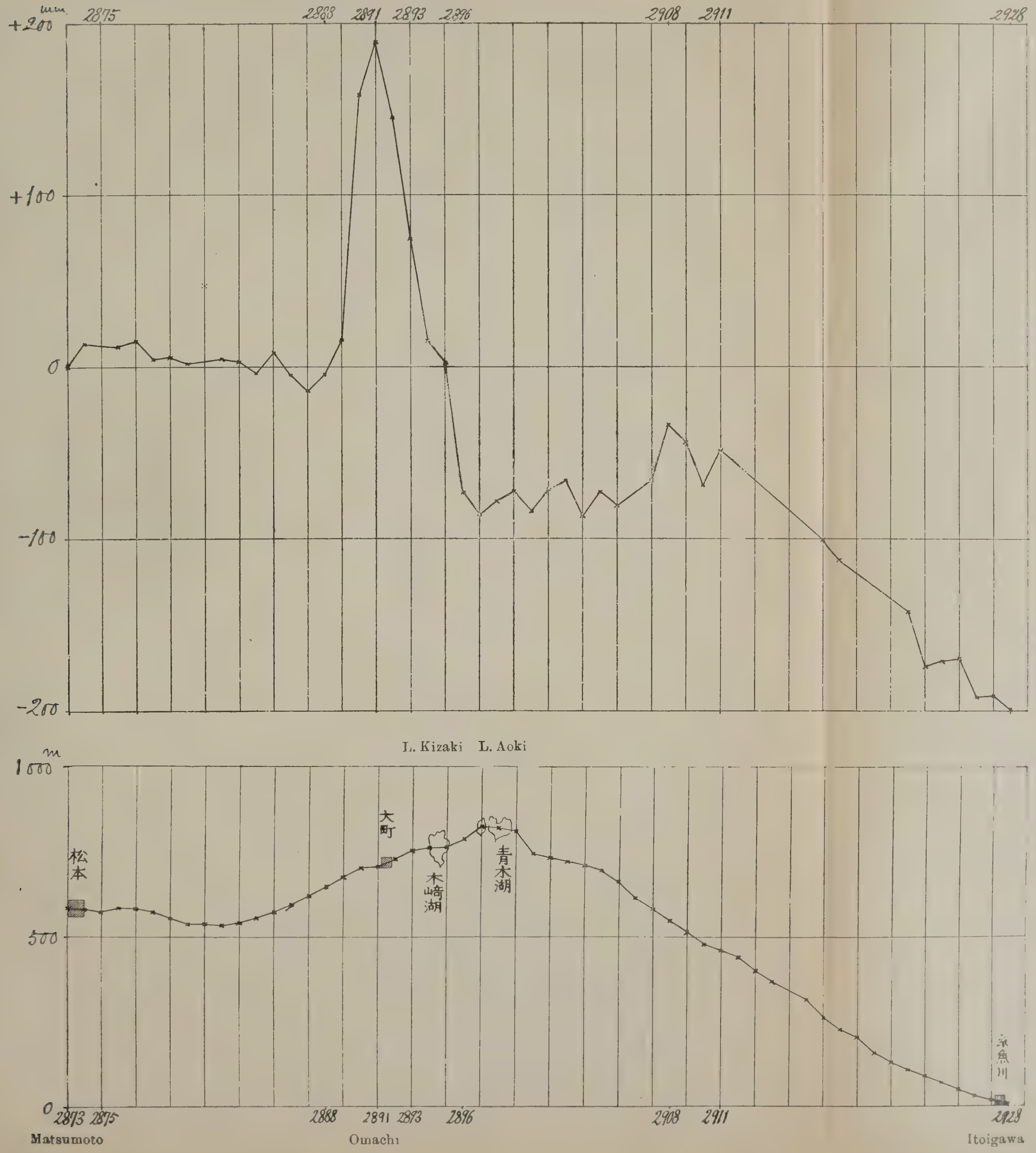
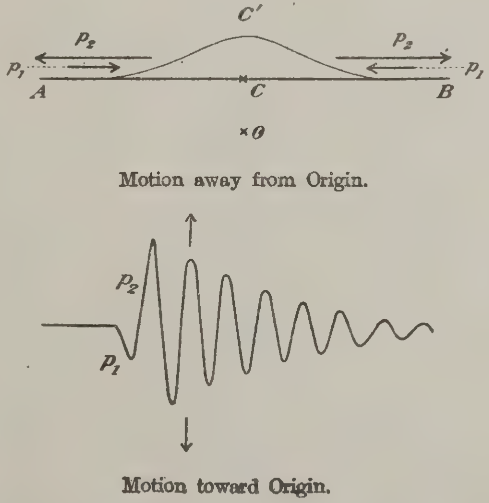


Fig. 21 indicates the position of the B.M. Nos. 2888 to 2895 in the vicinity of Omachi where the height change has been most marked. The maximum elevation was at or about the B.M. No. 2981 situated to the south of the town. The iso-elevation lines of 150 and 100 mm., which has been drawn only in a very imperfect manner from the material in hand, are also shown in the figure. The 150 mm. elevation line encloses an area extending in an N.E.—S.W. direction, whose major diameter approximately coincides with the epifocal zone of the two destructive earthquakes under consideration. (See fig. 2.)

In the map (fig. 2) are indicated two small dislocation lines formed in the Shimizu district of the Tokiwa-mra, with their eastern sides depressed. This comparative depression is probably the result of a subsidence of the region surrounding the central elevation area about Omachi and possibly continuous to the marked depression indicated by the B.M. Nos. 2896 to 2907 in the region adjacent on the north.

With regard to the simultaneous production of the (i) elevation in the area about Omachi and the (ii) depression in the adjacent region, the first was probably the principal event, as its locality coincides with the meizoseismal district about the seismic origins, the second being accessory disturbances necessitated by compensation from the surrounding or adjacent ragion. This supposition of the primary elevation impulse well agrees with the result of observation. Thus, if the ground at and above the seismic origin 0 (fig. 23) be suddenly upheaved, the very first displacement (p_1) at places A and B more or less distant from the epifocus, will be directed inwards, the next or counter displacement (p_2) being directed outwards. This is in accordance with the tromometer records obtained in Nagano and Tokyo. (See §§ 7 and 8). From the location of the (ii) depressed area to the north of the (i) elevated area, it may be assumed that the whole tract between the former and the Japan Sea coast had been undergoing a settlement combined with a horizontal pressure acting from the concave, or inner, side of the Japan Arc.

Fig. 23.



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TOKYO. May, 1928.

On the Shimabara Earthquake of Dec. 8, 1922.*

By the late Prof. **F. OMORI.**

(*With Plates* I—VII.)

A. Unzen-dake and the town of Shimabara.

Going back to historical times, the great outburst of Unzen-dake in the year 1792 was part of a phenomenon which had been going on for over four months. As premonitory shocks preceding the first period of volcanic activity, there had occurred already in the winter of 1791 several earthquakes which caused landslides on the hills around the town of Obama, resulting in the loss of two lives through burial of dwellings under the debris. Landslides also occurred at Shimabara and Mae-yama. At past midnight on the 10th of February, 1792, the volcano entered its second phase of activity with an explosive outburst. Detonations could be heard coming from Fugen-yama, one of its loftiest peaks, when at the same time a vent was formed near the shrine of Fugen, from whence were projected steam, earth, stones and immense quantities of mud. After this the volcano entered its third phase of activity with outpourings of molten lava. On the 25th of February disturbances started from a ravine called Anasako and lava began to flow out from the 30th. From April 21st the earthquakes gradually increased in intensity, and with every shock loosened quantities of rocks and sand which poured down from the mountain slopes. From midnight of that day until the dawn of the following, the earthquakes were particularly violent, causing damage to the castle of Shimabara with some casualties. On the 29th at the village of Nakakoba, situated on the southern flank of the mountain, a grove of camphor trees measuring 120 meters by some 50 to 60 meters was suddenly dislodged and hurled into the ravine below, practically filling up the hollow. Two very severe shocks occurred on May 21st. The whole southern flank of Mae-yama, from summit to base, broke away and considerably altered the shape of the mountain.

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* Articles contributed by Dr. Omori to the "Gakugei" Magazine. A.I.

The volcanic idea of the Mae-yama landslides might be dismissed as nothing more than mere speculation were it not for the fact that the future safety of Shimabara hinges on the verity or otherwise of this theory, and if the great landslides of Mae-yama in 1792 were really the results of an explosive outburst of this mountain, then we cannot escape the conclusion that in this old volcano there lie dormant dire potentialities for a powerful eruption which may be released in all its fury at any future moment, in which event the precarious position of Shimabara town and vicinity is obvious. However, in view of the four objections above given, I make bold to state that the great landslides were due, both directly and indirectly, to the effects of the earthquakes and not to any eruptive forces. Mae-yama is an old, extinct volcano and being composed of old and friable rock, landslides took place as a result of the strong earthquakes, but now that the loosely held materials have dropped off the mountain slopes, a repetition of these things is not be expected even should earthquakes visit the locality again. Furthermore, even should Unzen-dake erupt again with copious outflows of lava, no particular danger need be apprehended.

B. The volcanic activity of Unzen-dake in Shimabara.

The most active period in the history of Japanese volcanic eruptions was the 13 years between 1778 and 1792, during which interval there occurred eruptions of the following volcanoes :—the great outburst of Oshima (Idzu province) and that of Sakurajima between 1778 and 1782, the fearful eruption of Asama-yama in 1783, the detonations of the extinct volcano Hakone-yama, and finally the great eruption of Unzen-dake which continued for four months between the winter of 1791 and the spring of 1792. This eruption started from Fugenyama, one of the loftiest peaks in the central part of the Unzen-dake range, with outpourings of lava which flowed down the valley channels for a distance of more than four kilometers with, however, no casualties. Finally on the 21st of May, 1792, there was a deafening detonation, followed by a great landslide from the slope of Mae-yama, mentioned in the preceding paragraphs, and distant about four kilometers from Fugen peak, resulting in the descent of a terrible mudstream into the Ariake sea, causing thereby a large tidal wave. Mae-yama, however, being an old extinct volcano was destitute of volcanic energy, and while the earthquakes from Unzen-dake were not particularly severe, the worst ones were wont to cause earth-cracks from 5 to 10 cm.

wide, besides causing the cantings of dwelling houses and overturning of warehouses and the great landslide of Mae-yama.

Fully 120 years had elapsed since the turbulent years of 1778–1792, when with the year of 1909 was ushered in a new period of pronounced volcanic activity which lasted until 1915. This interval witnessed violent outbursts of the three very similar volcanoes of Oshima, Asama and Sakurajima, so that the disturbances of 1778–1792 were repeated in the same order even to the detonations of Hakone-yama, together with the disturbance of Unzen-dake, which latter, had been anticipated as the culmination of these activities. In these circumstances the numerous earthquakes which visited Nagasaki and vicinity at the time were nothing more than local shocks of volcanic origin.

According to the tromometer of the Seismological Institute (Tokio), the earthquake which was felt at 1 h 52 m 30 s on the 8th (Dec. 1922) was quite strong, the maximum having reached 2.8 mm. so that it was equal in severity to the strong shock that was felt at 6.30 in the evening of January 12th, 1914, which latter took place about ten hours after Sakurajima had began its eruption. At 7 h 23 m 58 s there was a small shock followed by one at 11 h 04 m 07 s, which could rank next in severity to the first one, and with a maximum movement of 1.7 mm., while another small shock was felt at 2 h 19 m 31 s in the afternoon. All these were comparatively strong shocks, and Shimabara and vicinity soon became the seat of frequent earthquakes of varying intensities.

Judging from the behaviour of Unzen-dake in the past, it is quite possible that earthquakes such as have recently happened may repeat themselves during the course of the next few weeks, but nothing of a destructive nature need be expected. We are now witnessing the usual characteristics of volcanic earthquakes, just as what happened during the eruption of this same volcano in 1792, and even should an eruption now take place there is no cause for uneasiness. That Unzen-dake will immediately begin an eruption is difficult to believe, and even were it to commence and keep up for some months, so long as the outbursts do not assume an explosive character, nothing serious is likely, still less a repetition of the disaster of 1792. Even should there be lava flows, they will go down the valleys and quiet down after travelling a few kilometers without endangering life or property. As to the earthquakes, while they may not be strong enough to overturn the Japanese style wooden houses, buildings and warehouses of bricks or stone may be overturned, but what needs to be particularly emphasised is the danger of falling rocks and debris from the hillsides. (Penned on the spot by the author on December 8th, 1922.)

C. The Earthquake of Shimabara Peninsula.

INTRODUCTION. The islands of Hokkaido, Honshiu, Shikoku and Kiushiu, together comprising the Japanese island chain, form a conspicuous arc with marked dissimilar features for the inner, or concave, side as contrasted with the outer, or convex, side of the arc. Judging by the systematic way in which the volcanoes and seismic centres are distributed, the Japanese island arc may, in a broad sense, be regarded as one great volcanic or seismic zone. Consequently, whenever the crustal stress accumulates the whole island arc is affected, and great eruptions and forcible earthquakes occur simultaneously in various parts of the country. In view of the intimate connection between volcanoes and earthquakes, it follows that whether they originate at widely separated localities, or whether they have occurred in the past or quite recently, or whether they may occur in the future, they all are more or less inter-related, so that careful observations of the distribution of these phenomena with respect to periodicity as well as to locality, ought to yield data justifying reasonable anticipations regarding the usual trend of these activities. Or we might say that every volcano has its particular characteristics, or *habits* so to speak, and in a way, the earthquake zones have also their respective habits, such as whether they are generally weak or strong, or whether their activities are generally preceded by feeble foreshocks or otherwise. It is the careful observations of these habits that is extremely desirable. Now, not only the Japanese island arc, but the entire Pacific margin may be regarded as one great seismic zone. It is noteworthy that in Japan and the Aleutian group, and in the clearly established island arcs of Java and Sumatra, the inner, or concave, side is generally the volcanic zone, whereas the outer, or convex, side is the seismic zone.

VOLCANIC EARTHQUAKES. Of types of these there are several and examples of some of them follow.

(a) Firstly, we have those which take place some hours, or even some days, before the actual eruption. Notable examples are furnished by the succession of shocks which heralded the Usu-san eruption of 1910, in Hokkaido, and the violent eruption of Sakurajima in 1914. In both cases the fore-shocks, gradually increasing in strength, kept on for from two to as much as four days after which the volcanoes burst out with all their fury, but the earthquakes, after having reached their maximum intensity, gradually quieted down. In the case of the eruption of Yakedake, situated on the boundary of the provinces of Hida and Shinano, and which started at 7.35 on the morning of June 6th, 1915, a succession of shocks kept up with hardly an intermission for almost 35 minutes before the eruption broke out.

(b) Secondly, we have those premonitory shocks, which, instead of gradually increasing in intensity, start off with several sudden strong shakings followed by a number of after-shocks, which, gradually diminishing in intensity, quiet down altogether when after a few quiet days the volcano begins its work. The examples fitfully illustrating this type are the two severe Asama shocks of May 26th, 1908 at 9.15 a.m. and of July 16th, 1912 at 7.46 a.m. These were followed by several hundred after-shocks that lasted for several days, but in both of these cases the eruptions of Asama-yama took place almost a year later. An historical example is that of the earthquakes which started to violently shake the environs of the town of Obama, in the Shimabara peninsula, on Dec. 10, 1791, which were followed in February of the succeeding year by an eruption of Fugen-dake.

(c) At certain periods volcanoes quite extinct like Hakone-yama become the seat of earthshaking detonations which are volcanic earthquakes.

(d) When explosions or eruptions originate in volcanoes the ground tremors that occur are volcanic earthquakes, although they are extremely feeble. This was experienced during the recent activities of Asama-yama when we were descending the mountain and were at a distance of about 4 km. from the summit. Tremors took place nearly 10 seconds before we heard the thunderous report of the explosions, but the tremors were not felt by our unaided senses.

We may say then that earthquakes felt at the base, or in the vicinity of it, are volcanic earthquakes, be the latter active, dormant or extinct, and whether an earthquake is volcanic or otherwise, there is no fundamental difference in their respective natures, the difference being simply confined to geographical characteristics. However, volcanic earthquakes do not go beyond a certain stage of intensity, being mainly local shocks of limited severity.

D. The Violent Shimabara Earthquake of 1922.

(An outline sketch.)

From about 4.15 p.m. of December 7th, 1922, there were felt several earthquakes, and while they were all fore-shocks, at about 1.50 a.m. of the following day there came the first severe shock. Another big one came at about 11.03 a.m. of the same day, although, by the tromometer at the Seismological Institute, Tokio, the maximum movement of the second severe shock was only slightly more than half that of the first big shock, that is to say, the first one was the most energetic of all the shocks that came, besides causing the most damage. Moreover, while the first strong shock overthrew houses, caused casualties and did other damages in the four villages of South Arima, North Arima, West Arie and East Arie, all lying in the southern part of the Shimabara peninsula, the second strong shock threw down houses, caused many casualties and did considerable havoc throughout the district lying between Obama hot-springs in the western, up to Kitamura in the northern, part of the peninsula. This difference in the affected areas was due to migrations of the seismic center, and, as will be shown hereinafter, the origin of the first strong shock was underneath the base of Fugen-dake, whereas that of the second strong shock was at a point underneath the southwestern base of the mountain, hence close to Obama. Again, according to the tromometer records of the Seismological Institute, Tokio, there were two fairly strong shocks at about 7.22 a.m. and at 2.17 p.m., respectively, on the 8th, which, when compared with the first and second severe shocks were quite feeble, but were felt rather strongly at places near the origin. The shaking which took place at 2.17 p.m. had as its epicentre a place very close to the city of Nagasaki, which had already suffered more or less from the effects of the first severe shock so that this city suffered again, although to a lesser extent with only such damages as cracks in walls and overthrown brick walls, etc. The number of after-shocks was, however, enormous, and, according to the tromometer records of the Nagasaki Meteorological Observatory, the number registered up to 5 p.m. of the 8th had reached already 600, including the fore-shocks which occurred about 4 p.m. of the 7th. After this the shocks began to diminish in frequency, but from the commencement up to noon of the 11th, the number of shocks registered reached the enormous total of 1417, although the majority of them were sensible only to instrumental records.

The casualties were as per Table I, namely, 27 killed and 35 wounded; 131 dwellings and 295 warehouses and outhouses destroyed.

Table I.

Village	Killed	Wounded	Collapsed houses	
			Dwelling	Non-dwelling
Kita-arima	13	16	46	142
Minami-arima	2	2	8	3
Higasi-arie	4	6	18	59
Nisi-arie	2	1	9	4
Katusa	2	2	7	17
Kutinotu	1	4	3	1
Obama	3	4	20	46
Kita-kusiyama	0	0	5	9
Minami-kusiyama	0	0	8	4
Dôsaki	0	0	1	3
Hutu	0	0	1	0
Hukae	0	0	1	1
Yamada	0	0	2	5
Hukabori	0	0	1	1
City of Nagasaki	0	0	1	0
Total	27	35	131	295

In the above table the casualties at Obama were mainly the result of the second strong shock which came at 11 a.m. on the 8th, while those of the rest were due to the first strong shock which came at 1.50 a.m. There was no damage to speak of at the Obama hotspring resorts. In the outskirts of the Unzen Kôen (Hot Springs Gardens) the second shock was felt more strongly than the first one, and while there were cracking of walls, overturning of stone fencings and such minor damages, the buildings did not suffer. At the Unzen Shrine a portion of the stone fencing was thrown down, but none of the stone lanterns were overturned, while at the Unzen Kôen neither the solfataras nor the fumaroles showed any signs of change.

The hamlet of Hashiguchi in North Arima was a heavy sufferer with destruction of 13 dwellings out of a total of 22 and 11 persons killed, while at the hamlet of Nakasugawa in North Arima four people were killed.

Table II. Casualties in the village of Kita-Arima.

Hamlet	No. of houses	Collapsed houses		Killed	Wounded
		Dwelling	Non-dwelling		
Hasiguti	22	13	9	11	11
Haiki	20	4	5	1	1
Oriki	48	1	10	1	1
(Other)	983	28	18	0	3
Total	1073	46	42	13	16

Table III. Casualties in the village of Higasi-arie.

Hamlet	No. of houses	Collapsed houses		Killed	Wounded
		Dwelling	Non-dwelling		
Kubo	—	1	2	0	2
Nakasugawa	—	4	4	4	2
Ogawa	—	7	15	0	1
Yamakawa	—	4	18	0	1
Onoue	—	0	2	0	0
Kabakawa	—	3	17	0	0
Total	—	19	58	4	6

In Kita-Takaku County, no dwelling collapsed, but some warehouses and outhouses collapsed as follows:

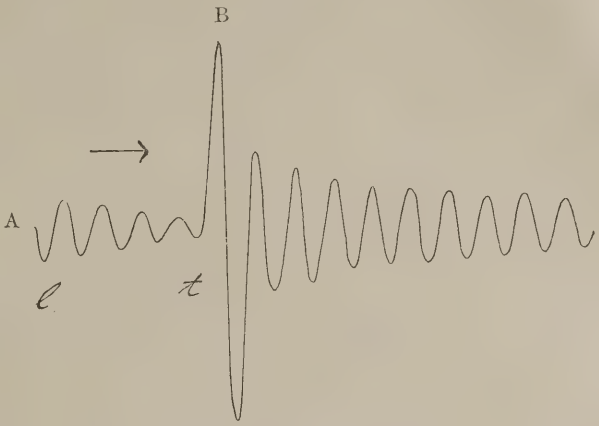
Ono Village 15, Tayui Village 4, Moriyama Village 3,
Enoura Village 4, Toisi Village 1.

A SHORT ANALYSIS OF EARTHQUAKE MOTION. As illustrated in Fig. 3 the earthquake motion begins with slight tremors A and after a little interval reaches the main phase B, after which it gradually diminishes in intensity. The preliminary tremor is therefore AB, and whether it be a sensible vibration or a microtremor, so long as it has originated at a near distance its duration is generally a few seconds or some tens of seconds, so that the distance of the seismic origin can be determined by an observer from the following formula

$$x \text{ km} = 7.42\, y \text{ seconds}$$

where x = distance from the observer to the orign and y = observed duration of the preliminary tremor. The explanation of the preliminary tremor is that from the source of the vibrations are propagated outwards, and simultaneously, two different waves, one longitudinal (A, Fig. 3) and the other transverse (B), but since the longitudinal waves have a higher velocity of propagation than the transverse waves, the former outraces the latter so that as the distance from the origin increases, the time difference in the arrival of the two waves also increases, or, in other words, the duration of the preliminary tremor is increased.

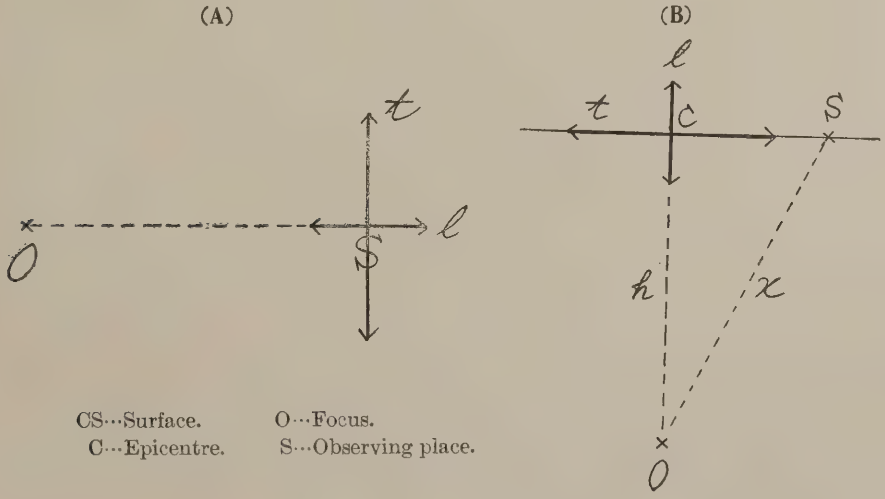
Fig. 3.



Ordinary earthquake motion.
A···Preliminary tremor. B···Principal portion.

In Fig. 4 the straght line OS represents the distance between the seismic origin O and the observing station S. The longitudinal waves

Fig. 4.

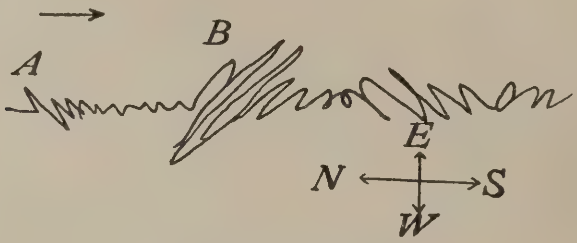


CS···Surface. O···Focus.
C···Epicentre. S···Observing place.

travel parallel with this line, thus indicating the direction of the origin, while the transverse waves being propagated in a direction at right angles to this line OS, do not indicate in a direct manner the direction of the origin.

The two earthquakes that originated at sea in a northeasterly direction from Formosa on the 7th and 15th of December of last year, furnished good examples of longitudinal and transverse waves. As actually registered (without resolution into its components) by the Duplex Pendulum Tromometer of the Seismological Institute, Tokio, Fig. 5, the initial tremor had a NE–SW direction thus indicating the direction of the epicentre, while the maximum horizontal motion shown at the commencement of the phase vibrated in a NW–SE direction, hence perpendicular to the first named motion.

Fig. 5.

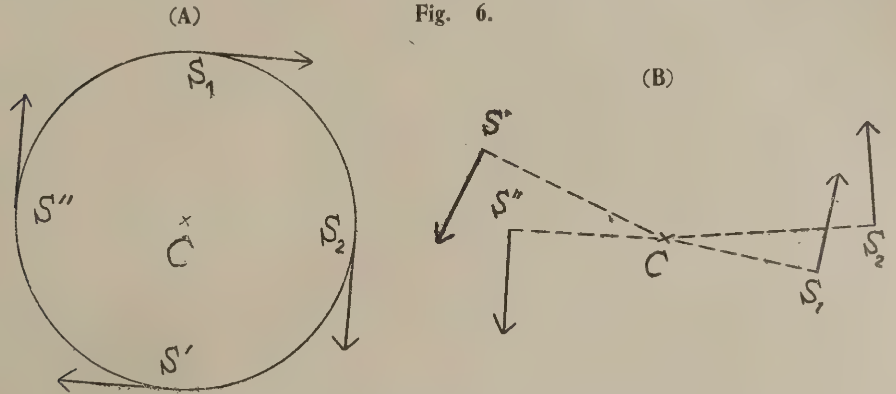


Horizontal earthquake motion.
A···Longitudinal waves or preliminary tremors. B···Transverse waves or principal portion.

The records obtained at Tokio of the severe earthquake of April 26th last year, which, besides shaking the Miura peninsula and the southern part of the Boso peninsula, shook also Tokio, Yokohama and its environs, show quite clearly the same results. The direction of the initial preliminary tremor was almost due S–N, from which, taking into account the vertical motion, the seismic origin was deduced as lying almost due south of Tokio, that is in the Uraga channel; whereas the direction of the initial main phase, which is the maximum horizontal motion, was nearly E–W, hence at practically right angles to the direction of the first motion. An examination of the records of the Mt. Tsukuba Seismological Station showed the direction of the maximum horizontal movement to be E by S and W by N, thus revealing the transverse nature of the waves.

The earthquake of 8th December, 1921, which originated in the S.E. part of the province of Hitachi was also strongly felt in Tokio, where the records also showed beyond doubt the preliminary tremors as longitudinal waves and the main motion as transverse waves. Again, in the case of the three severe earthquakes of June 20th, 1894, of December 8th, 1921, and of April 26th, 1922, seeing that, as compared with the maximum horizontal movement, the maximum vertical motion was very small, not more than about one-tenth of the former, it follows that the transverse waves which constitute the maximum motion are, in the main, horizontal vibrations moving normally to the vertical plane joining the origin, the epicentre and the observer's station. At all events, since at the epicentre, longitudinal waves become vertical movements while the transverse waves become horizontal movements, the vertical motions are comparatively weak, so that the strong motions are mostly horizontal. The fact that massive temple gates and the pedestal plates of stone lanterns and other objects in the Mino-Owari earthquake of 1891, and in the Shonai earthquake of 1894, moved laterally from one foot to as much as three feet, cannot but suggest very strong lateral movement, so that in the matter of earthquake proof construction the consideration of the horizontal motions is of paramount importance, far more so than the vertical motion, and so long as the effects of the former have been allowed for the effects of the vertical motion can be disregarded.

Fig. 6.



Diagrams illustrating the direction of the destructive earthquake motion in the neighborhood of the epicentre C.

s_1, s_2, s', s''···Different observing places in the epicentral area.

Assuming the transverse waves to constitute the principal motion of the earthquake movement, the actual displacement and the maximum acceleration, or, in other words, the destructive energy would be at its maximum at the origin, diminishing in intensity as it recedes from it, that is varies in inverse ratio to its distance from the seismic focus. If we take D for the focal depth and r for the distance from the observer's station to the epicentre, then both the amplitudes of vibration and the maximum acceleration vary inversely as $\sqrt{D^2+r^2}$, which fact would seem to disprove the idea that the seismic damage will be heaviest in the region where $r=D$, that is in the region whose epicentral distance equals the focal depth, rather than in the epicentral area.

OBSERVATIONS AT THE NAGASAKI METEOROLOGICAL OBSERVATORY. In connection with the recent earthquakes, the credit for the very complete tromometrical observations that were obtained at this station goes to the director, Mr. Mayeda, and his staff. In particular, the records taken of the first strong shock (see abridged reproduction in Pl. II.) by means of the Imamura pattern Seismograph in their regular use, form extremely valuable materials for investigation and study, inasmuch as, with the exception of the records obtained at the Seismological Institute, Tokio, of the severe earthquakes of 1894, 1921 and 1922, there is absolutely nothing like them in existence. According to the seismograms of the Nagasaki Observatory, while the actual maximum ground movement was 41 mm. in a direction N. 6° E–S. 6° W, if the initial motion of the preliminary tremor A was directed almost E–W, then the two motions would be perpendicular to each other. Since the origin lay to the east of Nagasaki, the preliminary tremor started with longitudinal waves, changing to transverse waves upon reaching the maximum phase, just as in the various examples cited. Now as AB is the preliminary tremor and B is clearly the beginning of the main vibration, the duration of the preliminary tremor is undoubtedly 6.6 sec. and calculating by means of the equation already given, the distance from Nagasaki to the origin works out to 49 km.

THE ORIGIN OF THE FIRST SEVERE EARTHQUAKE. As the seismograms and the tromometer records of the three observatories of Nagasaki, Kumamoto and Kagoshima clearly showed the duration of the preliminary tremors as well as the directions of the initial motions, the position of the epicentre, together with the focal depth, were readily determined, as in Table IV.

The durations of the preliminary tremors as registered by the observatories of Nagasaki, Kagoshima and Kumamoto being respectively 6.6, 8 and 18 secs., by describing on a map three circles with each

Fig. 7.

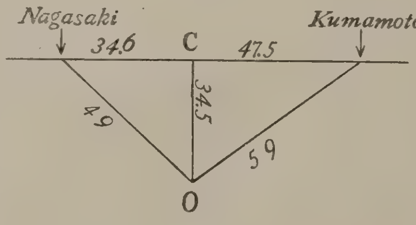


Table IV. **Results of observation of the first severe shock.**

Station	Duration prel. tr.	Focal distance	Epicentral distance	Direction of initial phase	Focal depth
Nagasaki	6.6 s.	49 km.	34.6 km.	S 84° E	34.5 km.
Kumamoto	8.0	59	47.5	S 70° W	
Kagosima	18.0	133	128.5	S 10°.6 E	

one of the three stations as centres and with corresponding focal distances derived from the above data as radii, we get a spherical triangle at the intersections of these circles, in which we must find the epicentre. (Pl. III.) Now the initial preliminary tremor indicated by the tromometer at the Kumamoto Observatory was extremely large, namely, 1 mm. and clearly indicated a S 70° W direction, and that of Kagoshima Observatory was 0.46 mm. with a S 10°.6 E direction, whilst that of the Nagasaki Observatory gave a direction of nearly S 84° E, so that the point of intersection of the directions of the longitudinal vibrational waves as registered at these three stations must also be the epicentre. The epicentral position as deduced by the preceding two methods lies near the point indicated by a cross on map, Pl. III. An essential condition for the determination of the epicentre is that all the observing stations when computing the focal distance should get identical results for the focal depth. As shown in Fig 7, the focal depth of the first severe shock was about 34 km. The epicentre marked by a cross in Pl. III lies in the southern part of the Shimabara peninsula and to the west of East Arie village; and also to the N.E. of the hamlet of Hashiguchi, North Arima, and a little to the north of the seashore of North Arie, while its distance from the Nagasaki Observatory is E by S., and approximately 34 km.

E. The Earthquake of the Shimabara Peninsula.

OBSERVATIONS AT KAGOSHIMA. The tromometer records of the recent earthquakes obtained by this observatory were very satisfactory, and much credit is due to its director, Mr. Maruoka. The magnitudes of the preliminary tremors and the directions of the shocks felt during the 8th of December are as follows :—

Table V. Results of seismic observation at Kagoshima Meteorological Observatory.

No.	Time of commencement	Initial phase	
		Magnitude	Direction
1	1h 52 m.	0.46 mm.	S 10°.6 E
2	11 04	0.38	S 12° E
3	14 17	0.12	S 19° E
4	2 10	0.068	S 19°.7 E
5	7 22	0.096	S 11°.6 E
6	22 33	0.046	S 21° E

By producing the lines representing these tremors in opposite directions they would point to the seismic origin, although the directions will not all be the same. For example, the origin of no. 2 points somewhat more to the west than that of no. 1 while the direction of no. 3 inclines still further to the west; and although shock no. 3 was not particularly energetic as felt at this station, the proximity of its origin to Nagasaki accounts for the very severe shaking felt at the latter city, and the more or less damage suffered there.

DIRECTION OF THE MAXIMUM HORIZONTAL MOVEMENT. As stated in a previous paragraph, destructive shocks felt at a station are mainly horizontal movements of transverse waves, and as its direction is normal to the vertical plane including the origin, the epicentre and the observing station, the direction of the maximum movement of two points lying, one on either side of the epicentre, are at right angles to each other, as shown in Fig. 6. In these circumstances the direction of fall of brick chimneys, stone lanterns, gravestones, and other such columns, invariably coincide with the direction of the maximum horizontal motion.

DIRECTION OF EARTHQUAKE MOTION WITHIN THE SEVERELY SHAKEN AREA. Within the severely shaken area, particularly in the villages of East Arie and North Arima (including the hamlets of Hashiguchi and Tanigawa), the overturned objects display a remarkable uniformity in direction as will be seen from the annexed tables :—

Table VI. Direction of overturning of stone-lanterns, grave-stones, &c.

Higasi-Arie	N, N, N, N, N, N10°E, N10°E, N10°E, N10°E, N15°E, N25°E, N25°E, N25°E, N25°E, N30°E, N30°E, N30°E, N35°E, N40°E, N40°E, N40°E, N40°E, N45°E, N75°E, N50°E, N60°E, N5°W, N5°W, N5°W, N5°W, N10°W, N10°W, N15°W, N25°W, N35°W, N50°W, N70°W, N80°W, N85°W, W, S, S, S, S, S, S20°E, S20°E, S65°E, S10°W, S20°W, S25°W, S30°W, S55°W, S65°W, S70°W, S85°W
Kita-Arima	S, S, S, S5°W, S5°W, S15°W, S10°W, S10°W, S10°W, S10°W, S15°W, S15°W, S15°W, S20°W, S20°W, S20°W, S20°W, S20°W, S20°W, S25°W, S25°W, S25°W, S25°W, S25°W, S30°W, S30°W, S35°W, S35°W, S35°W, S40°W, S10°E, S25°E, S25°E, S25°E, S30°E, S60°E, E, N15°W, N25°W, N, N5°E, N5°E, N30°E, N50°E, N60°E, N60°E, N80°E

In the meizoseismic area, the direction of overturning, which indicates those of maximum seismic motion at each locality due to the first severe shock, come out on the average as follows :—

Table VII.

A				B	
Kita-Arima	Urata & its vicinity	Kutinotu	Nakatuka	Higasi-Arie	Dôsaki
S 8° W	S 8° W	S 16° E	S 13° E	N 3° E	N 48° E

In A the direction was practically south, and in B northwards, as shown in map, Pl. I ; the locality marked with a cross being the epicentre so that the directions are in practical agreement with the diagram, Fig. 6, B. The direction of the maximum movement at Nagasaki was initially N 60° E, but as its opposite direction becomes S 60° W, it would come under A.

EXAMPLES OF SIMULTANEOUS OCCURRENCES OF EARTHQUAKES AND VOLCANIC ERUPTIONS BUT AT WIDELY SEPARATED LOCALITIES. The case of the recent first severe Shimabara earthquake and the eruption of Oshima in the Idzu island group, which took place almost simultaneously, is listed below with other similar occurrences.

(1) On the 8th of December, 1921, at 9.31 p.m., a severe earthquake shook the Kwanto regions, while during the period from about December

8th to the 10th, there was an eruption on the island of Suwanose lying to the south of the province of Satsuma, in Kiushiu, actively projecting smoke and flame.

(2) At 10.11 a.m. of April 26th, 1921, there was a severe earthquake in the Kwanto regions (Uraga Channel), whereas at 5 p.m. on the 25th there were eruptions of Asama-yama.

(3) On December 8th, 1922, at 1.52 a.m. and at 11.04 a.m., Shimabara peninsula and environs were violently shaken, whereas from about the same day the volcano of Mihara in the Idzu island group started into eruption with issue of lava, and did not become quiescent until January of the following year.

NAGASAKI EARTHQUAKES—PAST AND FUTURE. In the recent earthquake, within the reclaimed ground section of the city, there were some damages such as those to brick factory chimnies and dislodging of plaster walls and ceilings. The maximum horizontal movement as registered at the local observatory was 41 mm., but the movement at places on soft ground would have been quite double of this. However, when compared with the movement at Tokio on the occasion of the severe earthquake that originated in the Uraga Channel on the 26th of April, last year, it is not quite 32% of the Tokio movement. The earthquakes which shook Nagasaki during the years 1791–1792 at the time of the activities of Unzen-dake, were of the same order of magnitude. At any rate, the northern part of Kiushiu is one of the zones of low seismicity in this country, hence the district is regarded as immune from very destructive shocks. This is bourne out by the fact that the historical record of earthquakes for Nagasaki is quite a small one, as will be seen from the following lists.

(1) The 14th of October, 1691, was a Saturday, when at dawn the inhabitants were aroused by two violent shocks, and although they were both short ones, lasting not more than 30 seconds, they were very severe, so much so that the pilot of a Dutch vessel anchored in the bay was thrown out of his bunk, while on shore dogs and poultry set up quite a commotion. (I am much indebted to Mr. D. Arai of Nagasaki who kindly allowed me to extract the foregoing from his copy of Kaempfers " Japan.")

(2) From about 1 on the morning of the 31st of October, 1725, severe earthquakes began to rock the city, and continued for three days when over 80 shocks were counted.

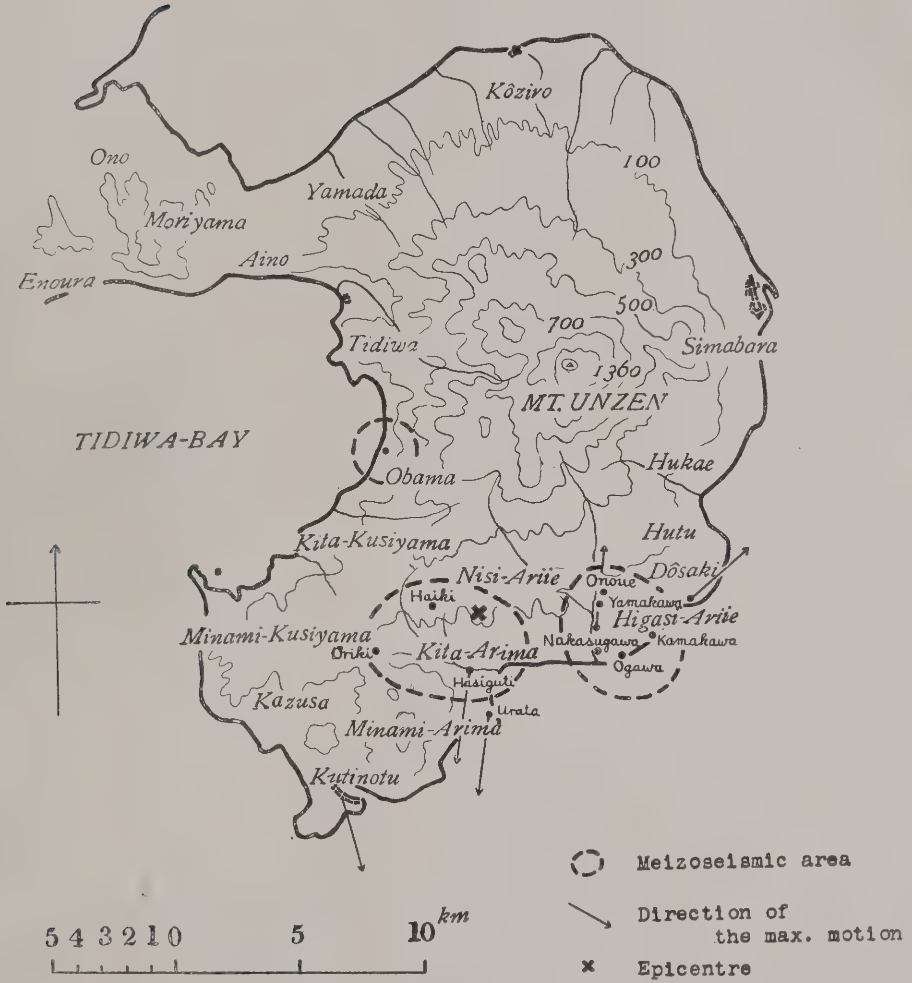
The earthquakes of 1691 having occurred more than 30 years after the eruptions of Unzen-dake of 1657 and 1663, it is not possible to conceive of any connection existing between the two phenomena, although, if some such a conception is permissible, the claim for it should belong to the eruption of Aso volcano which broke out in 1691, the very same year.

The earthquakes of 1725 did not follow close on the heels of the activities of the Kiushiu volcanoes, which were the violent outbursts of Kirishima in 1716 and 1717. Between the years 1717 and 1733 Asama had erupted several times, while the Iwate volcano erupted in 1719, but during all this interval, Unzen-dake, situated so close to Nagasaki, failed to evince the slightest sign of activity. This would support the conclusion that the Nagasaki earthquakes were of a purely local character, and while the shocks were somewhat strongly felt, the damage wrought was slight, hence far from being destructive. In these circumstances our belief is that, although strong earthquakes may visit Nagasaki in future, it is not likely that they will be worse than example no. 2 above, nor much stronger than those just recently experienced, therefore, with reasonable care and attention bestowed on the construction of houses, and also in civil works as well, towards making them as near earthquake-proof as possible, immunity from future earthquake disasters ought not to be unattainable.

CONCLUDING REMARKS. While such disasterous earthquakes as the Tokaido earthquake of Dec. 23, 1854, and the Nankaido earthquake of the day following, both of which originated in the sea-bottom of the Pacific facing the outer side of the Japanese island arc, and having no connection whatsoever with any volcanic system, may be extremely destructive, there is, however, a limit to the destructivity of volcanic earthquakes. The recent earthquakes which originated in the Shimabara peninsula may well be regarded as volcanic in nature, and the first severe shock that emanated from the southern base of Unzen-dake at 1.52 a.m. of December 8th was almost of the same order of magnitude as the strongest one of the many shocks that originated with the eruption of Sakurajima in 1914, although it was a little stronger than the shocks that accompanied the recent eruptions of Asamayama and Usu-dake (Hokkaido). At all events, it would seem to typify the strongest shock that is ever likely to shake the Shimabara peninsula and environs, and even were more or less heavy shocks to occur in this region in the future, they are not likely to be disasterous ones, nor is it likely that they would repeat themselves in the same locality. Again, although as a result of the severe earthquake of the 21st of May, 1792, an enormous landslip took place from the slope of Mayeyama, precipitating into the Sea of Ariake such an avalanche of soil and debris that a big tidal wave resulted, the forces that induced this landslide having done its work and gone, there are at present no potential causes remaining that are at all likely to bring about the repetition of such a gigantic landslide. Moreover, as a result of the great changes of 1792, the base of the mountain is now at such a distance from the sea that the tidal-wave hazard is also non-existent.

Neither is there any cause for anxiety over the habits of Unzen-dake in the future. While the destructive energy of volcanoes in blasting away parts of its sides, in short, its explosive outbursts, are terrible to contemplate, the eruptions of Unzen-dake will be confined to gentle or moderate actions without at all reaching the explosive stage. In both the eruptions of 1657 and 1792, lava flowed out from a spot a little below the northeastern part of the summit of Fugendake, but there were no showers of sand or ashes, and the whole action was so quiet and orderly that people visited the scene of action with impunity. There are good reasons for assigning Unzen-dake's present centre of volcanic activity to a place near the summit of Fugen-dake (peak). On the other hand, the chances of a new eruption breaking out from such a seat of ancient activity as Unzen-Kôen are scarcely worth considering, and furthermore, even should Fugen-dake itself break out again in the future, the most it is likely to do is to repeat such action as has been described in this paragraph, so there need be no misgivings in connection with the future behaviour of this volcano. (A descriptive outline of the eruption of Unzen-dake of 1792 was contributed by the author to the Feb. number of the " Gakugei Zasshi.")

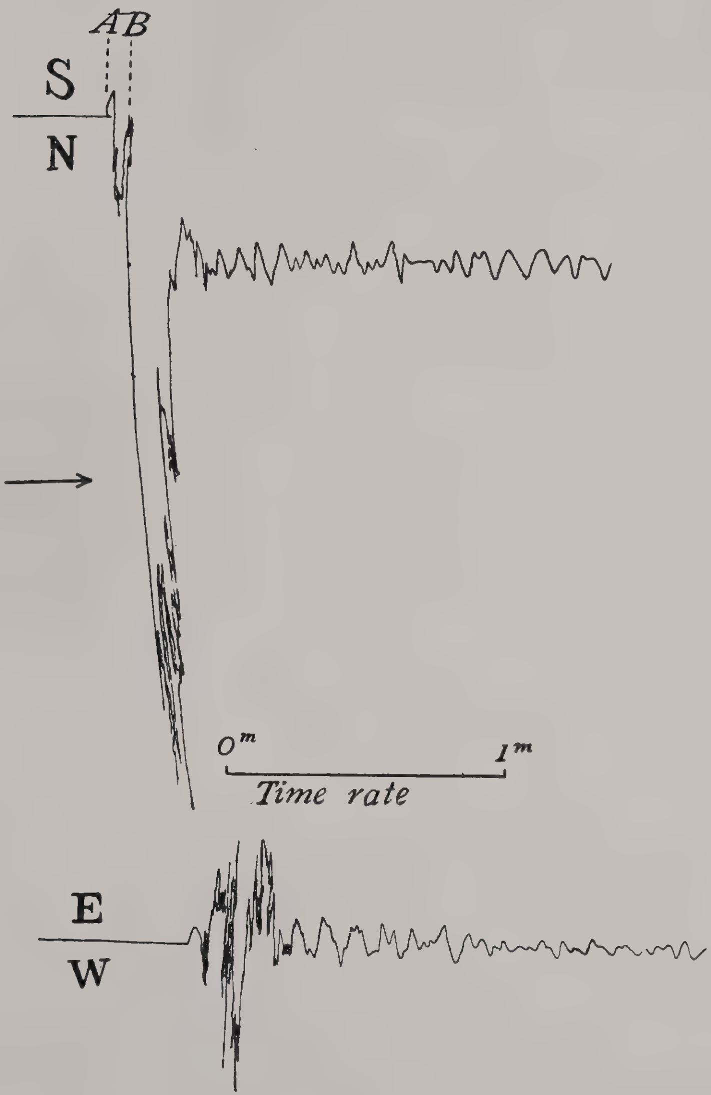
Seismic area of the Shimabara earthquake.



(After Imamura and Kodaira.)

Nagasaki observation of the earthquake of Dec. 8, 1922, at 1 h 50 m.

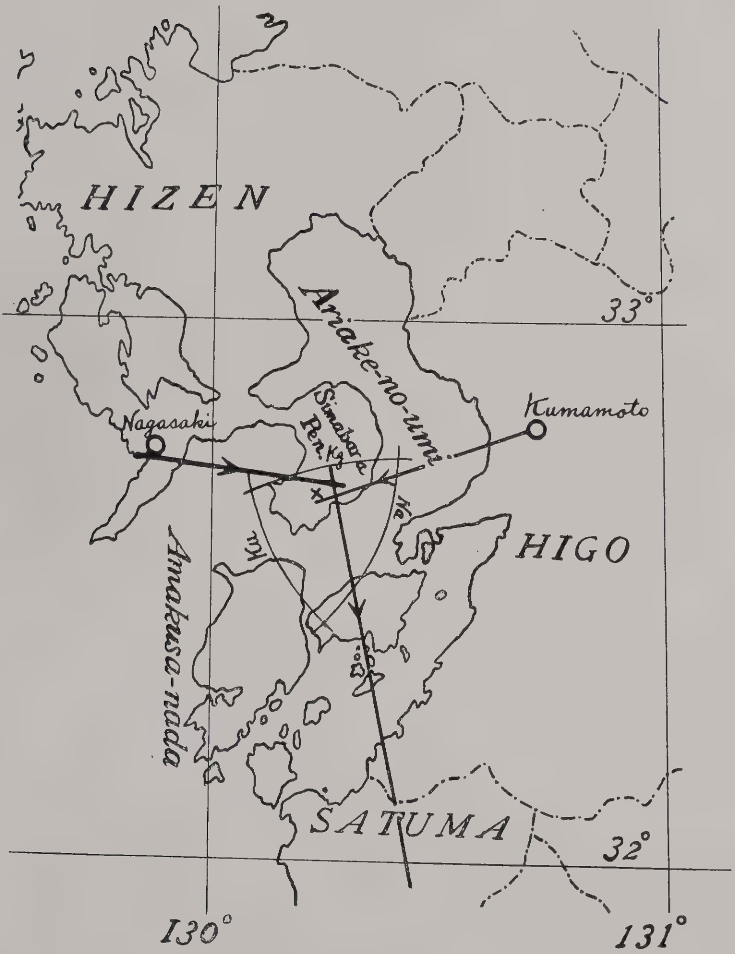
(Statical magnification = 2.)



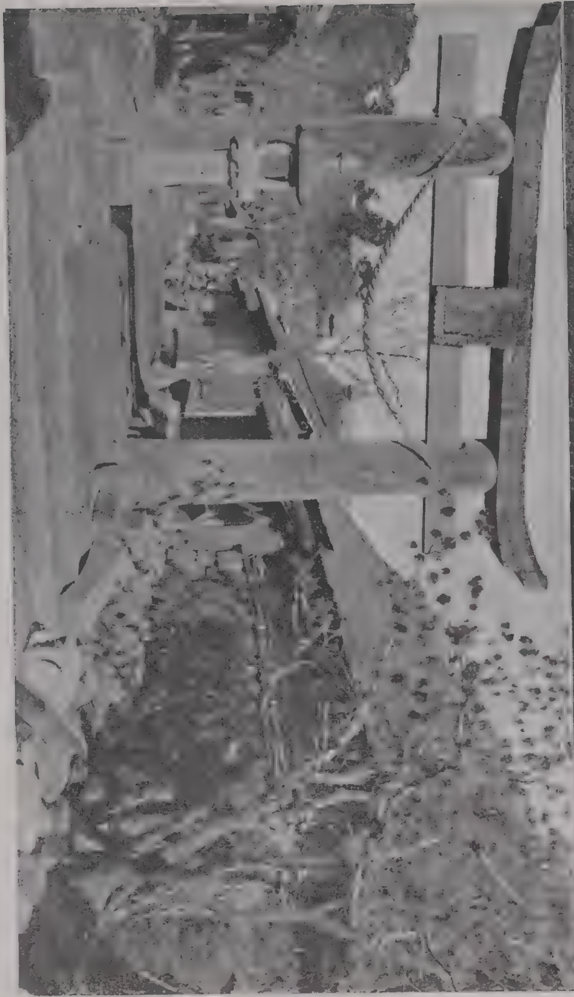
Pl. III.

Map showing the position of epicentre of the first shock as revealed by the observations at the different stations.

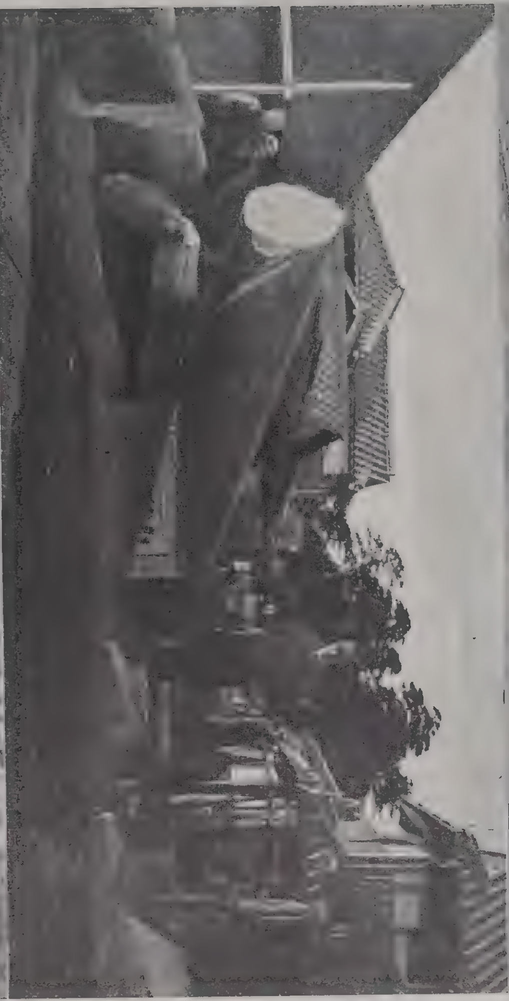
arrow............direction of initial phase,
arc ....focal distance (calc.),
cross ....epicentre.



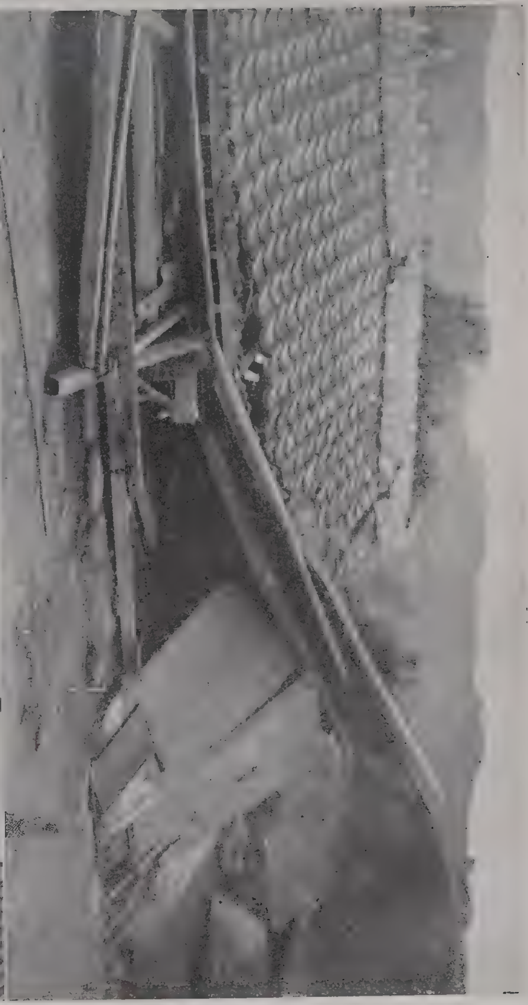
Pl. IV.



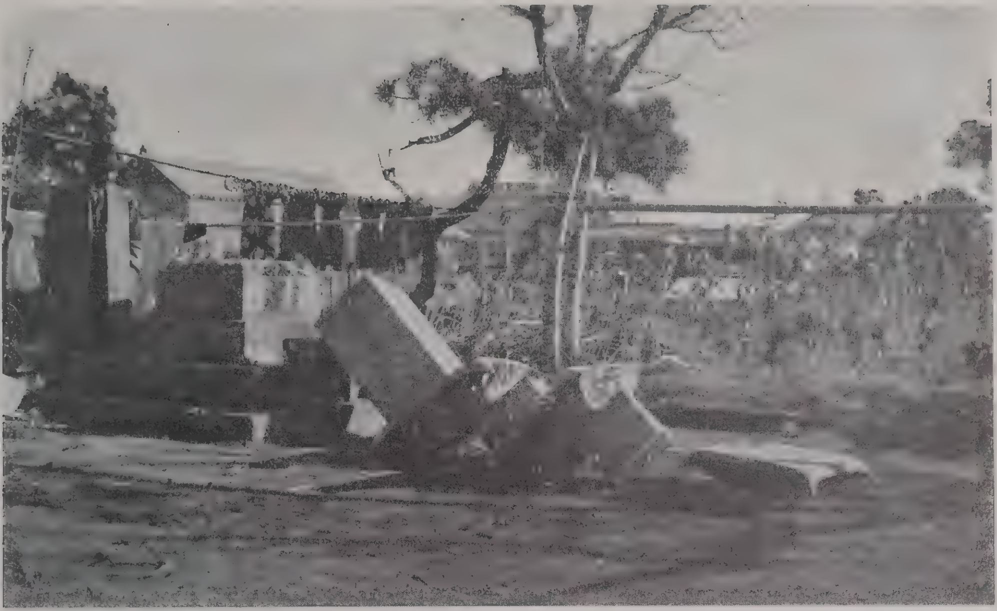
A *Torii* at Higashi-Arie displaced as much as 5 cm. One of a pair of stone lanterns in front overturned and the other remained intact.



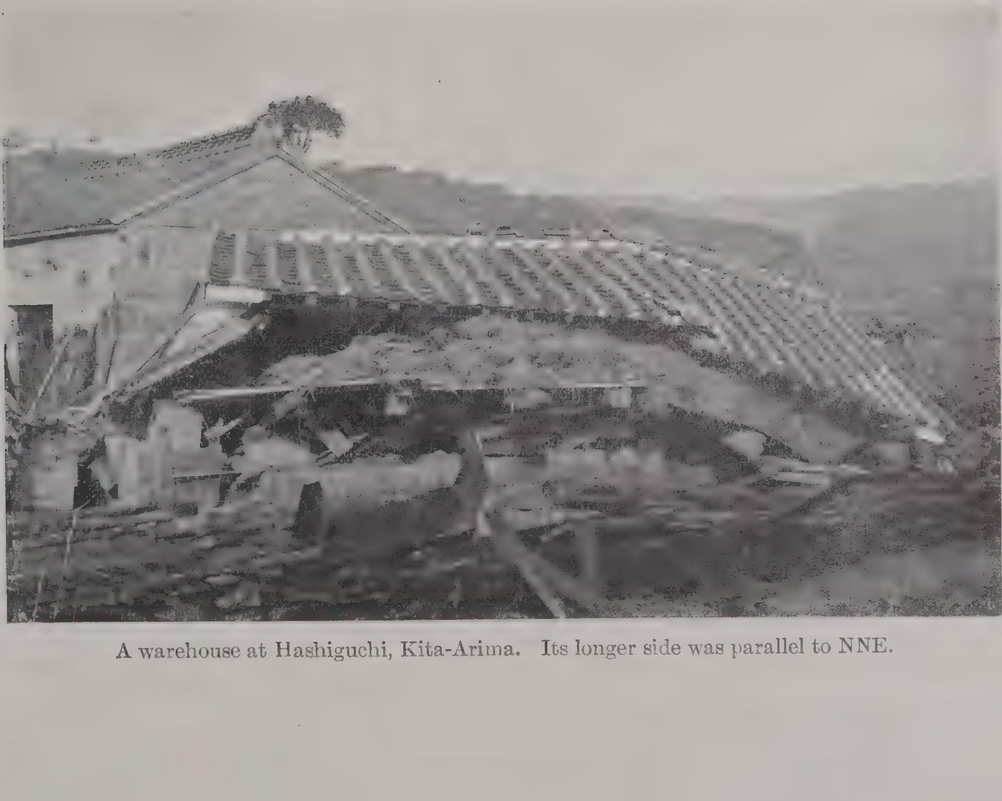
A *Torii* (shrine-gate) overturned at Sukawa, Nishi-Arie.



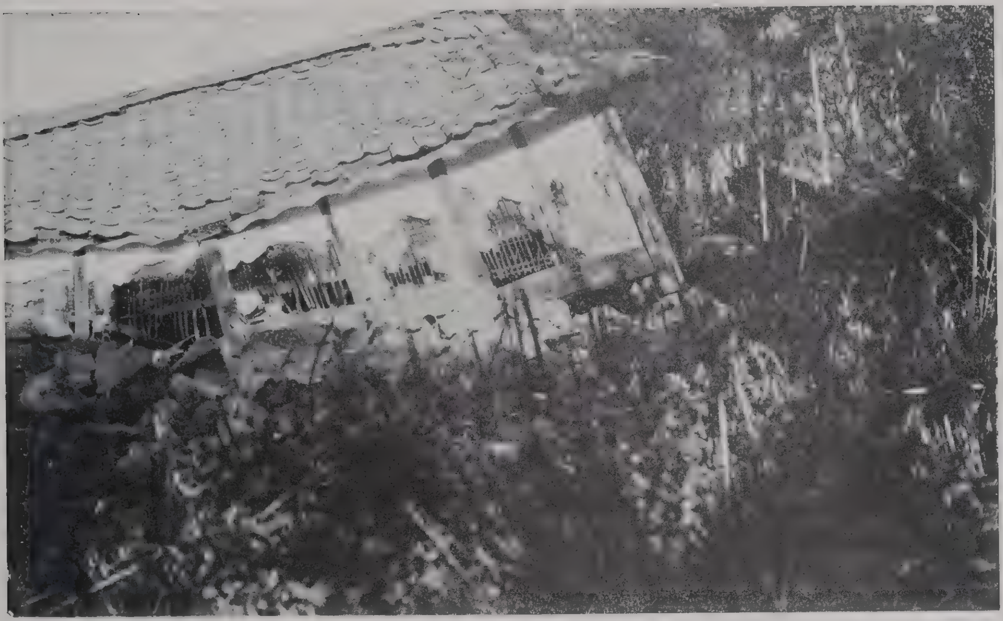
A collapsed house at Tsukanoyama, Minami-Kushiyama.



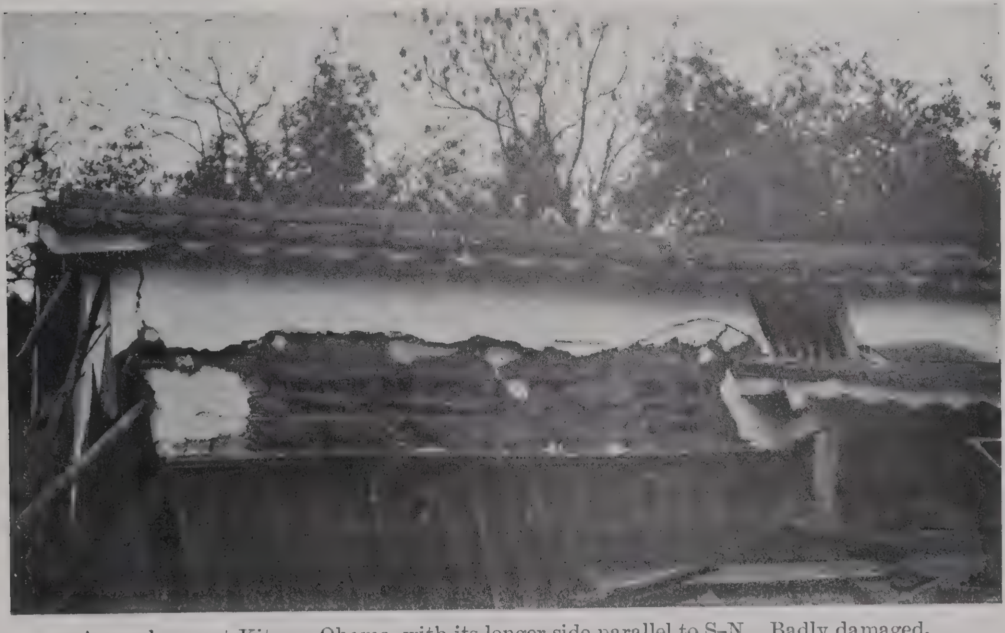
A five-storied stone monument at Higashi-Arie overturned, the two upper stories eastwards and the three lower ones westwards.



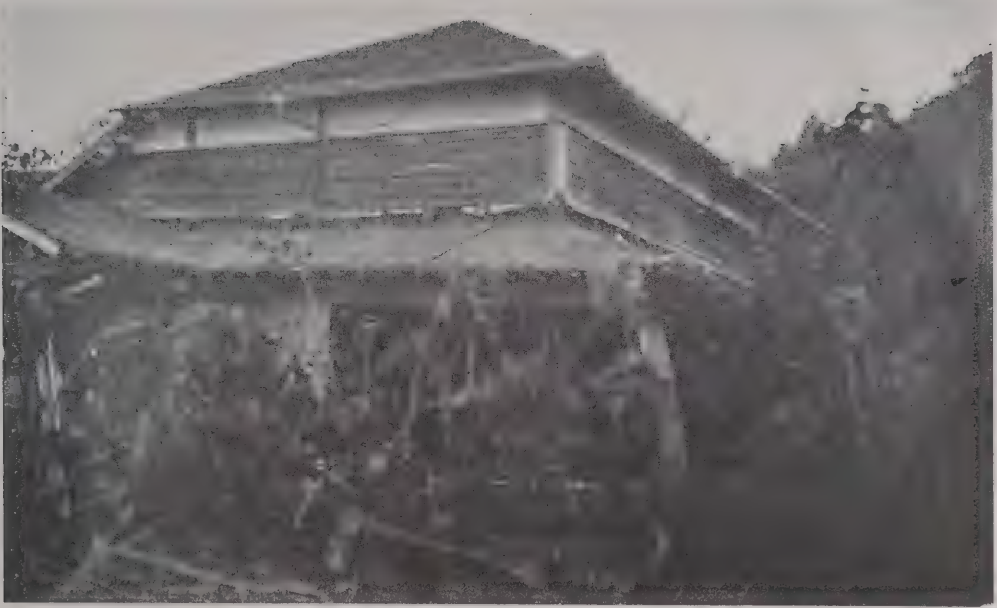
A warehouse at Hashiguchi, Kita-Arima. Its longer side was parallel to NNE.



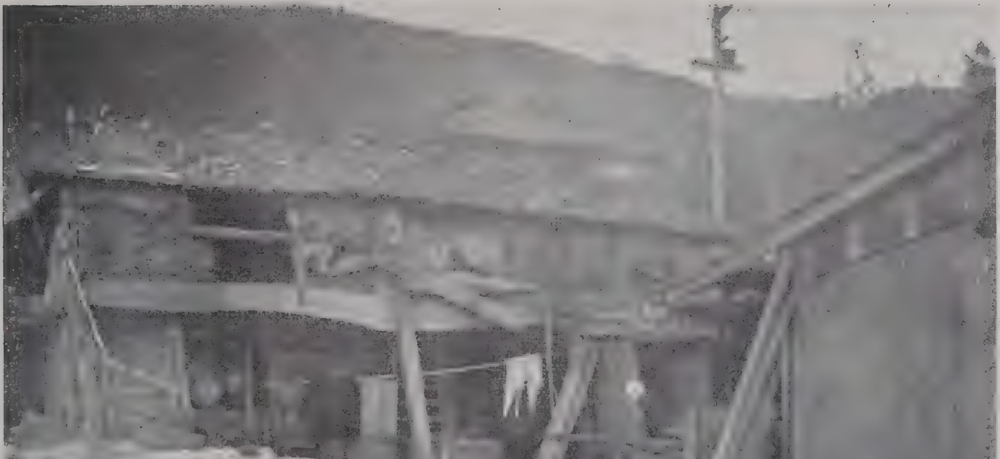
A warehouse at Kitano, Obama, with its longer side parallel to E–W. It was built upon a loosely constructed stone-foundation.



A warehouse at Kitano, Obama, with its longer side parallel to S–N. Badly damaged.



A dwelling at Kitano, Obama, with its longer side parallel to E–W. 8 pillars broken.



A warehouse at Kitano, Obama. Badly damaged.

Report on the Changes in the Land-Level in Connection with the Simabara Earthquake of 1922.

By **A. IMAMURA.**

(*With Plates* I and II.)

Realizing that, in connection with the earthquake that shook Simabara and environs on the 8th of December, 1922, some displacement more or less in the land-level would be inevitable, the late Dr. Omori, with the assistance of the Imperial Academy, succeeded in arranging for a survey of the affected area at the hands of the Land Survey Department. This body promptly organized a suitable surveying party and commenced work in June, 1922, but Dr. Omori, unfortunately, did not live to see the completion of the work. The survey was, however, pushed forward, and with the aid of funds augmented by our Committee in October of the same year, the work was in due course brought to a conclusion when reports on the result of the survey were presented by the two members of the Survey, Messrs. Y. Ogata and J. Onohara. It is with much pleasure that I take this opportunity to offer our thanks to the Imperial Academy who sponsored the undertaking, and to the governing council of the Land Survey Department as well as to the two gentlemen above mentioned.

A perusal of the reports makes it clear that changes in the land-level did take place, thus vindicating our anticipations. It must be noted, however, that the last surveys were made as far back as 30 years ago; the section between Isahaya and Kutinotu in July–September, 1894, and that between Isahaya and Hukabori during October–December, 1897. While in the circumstances, some changes more or less during the interval must be expected, the mean tide-level at the Hukabori Tide-gauge station showed a rise of only 2 or 3 cm., which difference, when compared with the results of the surveys for sea-level made before and after the interval in question, is altogether negligible in the first approximation. The outstanding changes observed in the land-level will now be given.

(1) Between benchmarks No. 5381 and 5394, that is between Kigitu and Nagasaki, the maximum uplift reached 64.5 cm. It is likely that these marks were once removed without any notice being given to the military authorities.

(2) Between benchmarks No. 4265 and 4270, that is between Isahaya and Aino, the maximum elevation was 8.3 cm., and the minimum depression 7.2 cm.

(3) Between benchmarks No. 4288 and 4290, that is in the northern part of the area affected by the earthquake in question, the maximum elevation was 34.2 cm. These marks were also once removed.

(4) Leaving Isahaya and following the eastern coast of the Simabara peninsula, we reach at its southern extremity the village of South Arima. In this section of the country, with the exception of the E. extremity of the peninsula between B. M. No. 4287 and 4292, there was an allround uplift of from about 3 cm. to 6 cm., whereas about Kutinotu no elevation at all could be detected. On the other hand, the E. extremity of the peninsula showed a slight depression in comparison with the adjacent land.

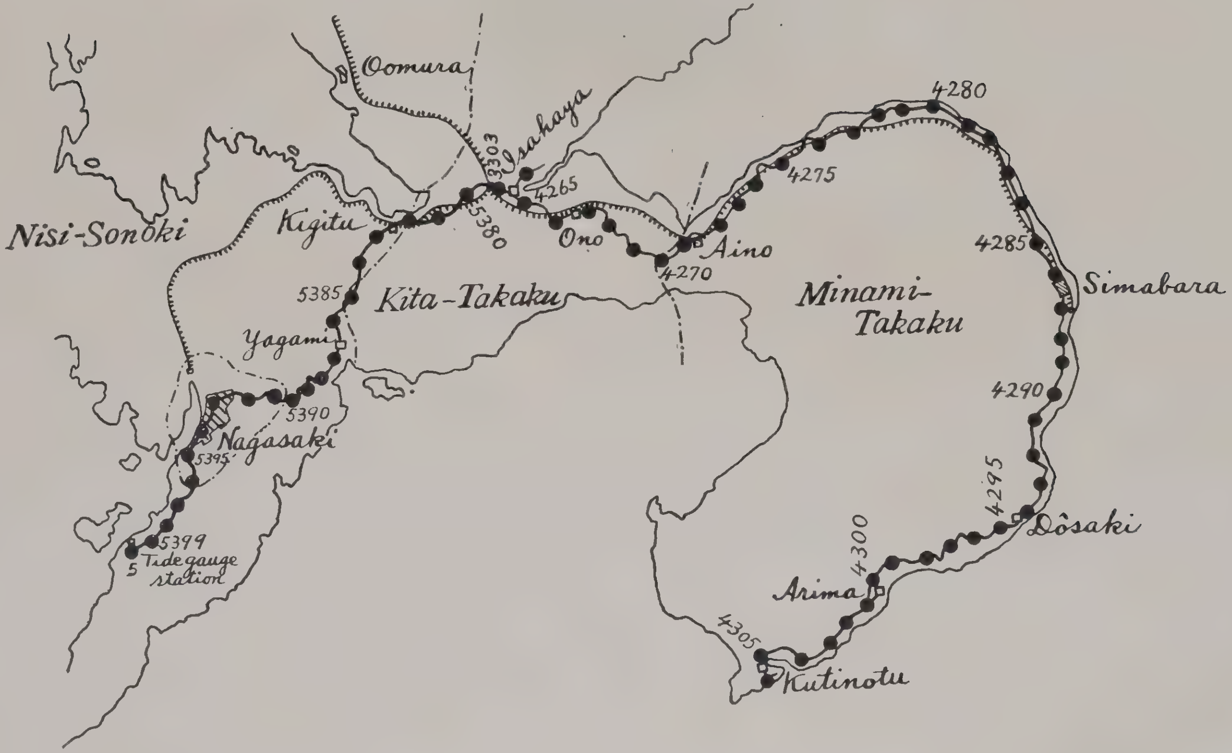
While it is a matter for regret that this survey covered only the northern and eastern coastlines, leaving out the western coastline, considering that the latter section had never been previously surveyed, it was unavoidable. Another matter to which attention may be called is the fact that the change in sea-level during a period of more than 23 years as observed at Hukabori, and just referred to, would seem to suggest a subsidence of as much as 2–3 cm., rather than an elevation.

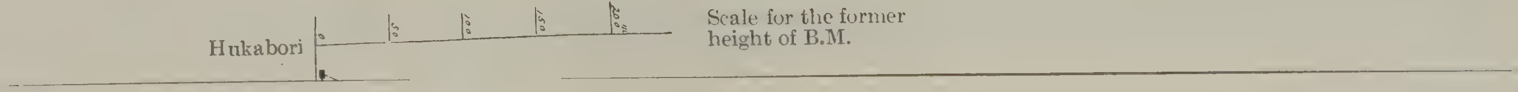
Be that as it may, it appears that there occurred, besides a slight upheaval of land for the most part of the peninsula, a very characteristic topographical change, which may be regarded as accompaniments of the present earthquakes, at two places, namely, one at the isthmus connecting the peninsula to the main land, and the other at the eastern extremity of the peninsula. This may suggest that there were two seismic centres, one in the heart of peninsula no. 4 and the other in the bottom of Tidiwa Bay no. 2 As, of the two centres, the former accompanied more conspicuous changes than the latter, it may be said that the most active centre was situated in the bottom of Tidiwa Bay.

Precise Levelling between Hukabori and Kutinotu: Comparison of the Heights before and after the Simabara Earthquake of Dec. 8, 1922.

Bench mark	Height in 1925 α	Height in 1894–1897 β	Height difference $\alpha-\beta$	Bench mark	Height in 1925 α	Height in 1894–1897 β	Height difference $\alpha-\beta$
	m	m	cm.		m	m	cm.
Tide gauge station	4.2112	4.2112	+ 0.00	5398	2.3226	2.3074	+ 1.52
5	3.0954	3.0474	+ 4.80	5397	141.6720	141.6482	+ 2.38
5399	7.0652	7.0516	+ 1.36	5396	46.9539	46.9259	+ 2.86

Map showing B.M. line from Hukabori to Kutinotu.



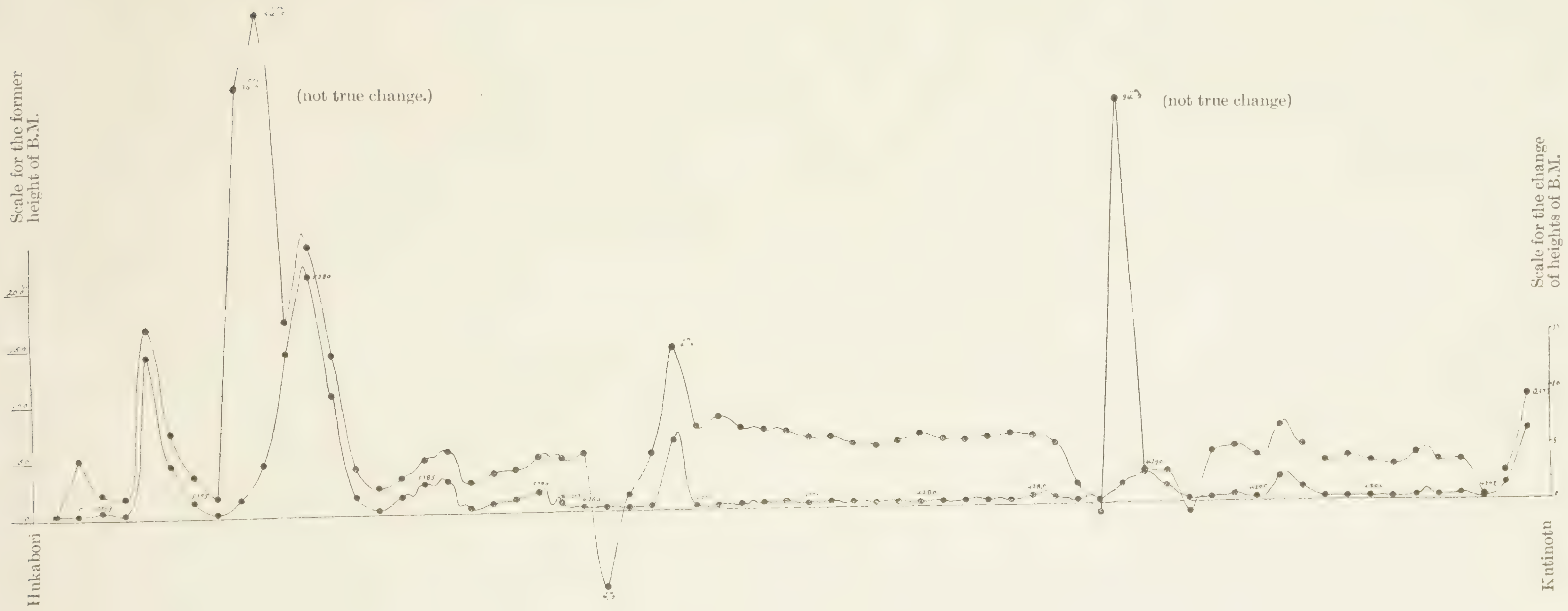

Hukabori
0
50
100
150
200m
Scale for the former height of B.M.

Diagramatic view of the former heights and the changes of heights of B.M.

The heights of B.M. in 1894–1897 are indicated by the lower curve with the scale on the left hand side.

The changes of heights of B.M. relative to the above-mentioned curve are indicated by the upper curve with the scale on the right hand side.

Each dot indicates the position of B.M.



Precise Levelling between Hukabori and Kutinotu: Comparison of the Heights before and after the Simabara Earthquake of Dec. 8, 1922. (Continued.)

Bench mark	Height in 1925 α	Height in 1894–1897 β	Height difference $\alpha-\beta$	Bench mark	Height in 1925 α	Height in 1894–1897 β	Height difference $\alpha-\beta$
	m	m	cm.		m	m	cm.
5395	13.3503	13.3273	+ 2.30	4278	4.0062	3.9559	+ 5.03
5394	2.7586	2.7440	+ 1.46	4279	4.1786	4.1228	+ 5.58
*5393	15.0352	14.6728	+ 36.24	4280	3.8360	3.7760	+ 6.00
*3592	46.6466	46.0018	+ 64.48	4281	4.1764	4.1203	+ 5.61
5391	143.6248	143.5976	+ 2.72	4282	4.2254	4.1714	+ 5.40
5390	210.3740	210.3479	+ 2.62	4283	4.4294	4.3734	+ 5.60
5389	106.8628	106.8287	+ 3.41	4284	4.4759	4.4165	+ 5.94
5388	16.3916	16.3663	+ 2.53	4285	8.5423	8.4903	+ 5.20
5387	3.1283	3.1083	+ 2.00	4286	7.5696	7.5229	+ 4.67
5386	16.1633	16.1456	+ 1.77	4287	3.3882	3.3734	+ 1.48
5385	26.6275	26.6074	+ 2.01	4288	3.1712	3.1837	− 1.25
5384	29.9065	29.8798	+ 2.67	*4289	17.4938	17.1513	+ 34.25
5383	4.0029	3.9798	+ 2.31	4290	28.3879	28.3869	+ 0.10
5382	8.4753	8.4480	+ 2.73	4291	15.1645	15.1518	+ 1.27
5381	10.2860	10.2599	+ 2.61	4292	3.4829	3.4961	− 1.32
5380	18.7110	18.6801	+ 3.09	4293	3.7311	3.6887	+ 4.24
3303	8.8817	8.8427	+ 3.90	4294	6.6462	6.6034	+ 4.28
3303	8.8817	8.8427	+ 3.90	4295	4.5750	4.5363	+ 3.87
4265	4.8434	4.7966	+ 4.68	4296	21.7369	21.6918	+ 4.51
4266	3.0276	3.0988	− 7.12	4297	12.0113	11.9734	+ 3.79
4267	2.8812	2.8706	+ 1.06	4298	3.6481	3.6158	+ 3.23
4268	3.8414	3.7948	+ 4.66	4299	3.3483	3.3114	+ 3.69
4269	61.8540	61.7711	+ 8.29	4300	3.9871	3.9548	+ 3.23
4270	4.2160	4.1460	+ 7.00	4301	3.4725	3.4439	+ 2.86
4271	4.0771	3.9987	+ 7.84	4302	4.0689	4.0320	+ 3.69
4272	4.9610	4.8926	+ 6.84	4303	4.3557	4.3232	+ 3.25
4273	5.1619	5.0967	+ 6.52	4304	6.3451	6.3153	+ 2.98
4274	6.4285	6.3650	+ 6.35	4305	2.7348	2.7328	+ 0.20
4275	4.4967	4.4383	+ 5.84	4306	15.1522	15.1422	+ 1.00
4276	5.7650	5.7079	+ 5.71	(7)	61.3313	61.2914	+ 3.99
4277	4.7964	4.7448	+ 5.16				

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* B. M. No. 5393, 5392 and 4289 had been removed from their original positions before the second survey was carried out.

Seismographic Study of the Simabara Earthquake.

By **A. IMAMURA.**

(*With Plates* I and II.)

With reference to the severe earthquake which visited Simabara peninsula on the 8th of December, 1922, several reports and addresses were made at the committee meetings by members at the time, but, unfortunately no summarised report has yet been presented. It was consequently arranged that, as the late Dr. Omori's contribution, a generalised report be compiled by using as material the articles which were contributed by the deceased to the " Gakugei " magazine, together, amongst other matters, with the results of the surveys made of changes in the seal-level in the affected districts. While engaged in this work, however, as a result of my own independent investigations of the seismograms and reports of the earthquake in question, I arrived at certain conclusions which are diametrically opposed to those reached by our late esteemed colleague. These were duly laid before the members at one of our meetings for their discussion, but I do not deem it inappropriate to set down here again the points over which we aie in disagreement, and which are as follows :—
According to Dr. Omori

(a) " The maximum phases, which are mainly transverse waves, " become horizontal vibrations with a direction at right angles to the " vertical plane including the origin, the epicentre and the observer's " station.

(b) " Since at the epicentre, longitudinal waves become wholly " vertical vibrations while the transverse waves become wholly hori- " zontal vibrations, even at the epicentre the vertical motions are " comparatively small so that the energetic motions are mostly the " horizontal ones. At the epicentral regions in the Mino-Owari and " Sakata earthquakes, massive temple gates and pedestals of stone " lanterns moved as much as 1 foot to 3 feet, indicating strong hori- " zontal movements so that in the matter of earthquke-proof construc- " tion it would seem that the horizontal motions are far more to be " dreaded than the vertical ones, so that as long as the structures are "built to withstand the former no attention need be paid to the "latter.

(c) "According to the seismograms obtained at Nagasaki the "maximum actual ground movement was 41 mm. with direction "N 6° E and S 6° W so that if the commencement of the preliminary "tremor were nearly E–W, the direction of the two motions would be "perpendicular to each other.

(d) "The duration of the preliminary tremor works out to 6.6 "sec., the correctness of which is beyond doubt."

Now, as stated by Dr. Omori, the direction of maximum motion as registered by the Nagasaki seismograph was N 6° E and S 6° W, but it would seem that an error was inadvertently committed in placing the direction of the initial preliminary tremor as E–W. As the preliminary tremor was 3.3 mm. S and 1.9 mm. E this makes an angle of 36° with the direction of the maximum phase above mentioned, hence, if anything, it is nearer to a parallel direction than one at right angles. In all probability it arose through Dr. Omori having accepted as axiomatic his generalization as quoted in (a) above. It is of course true that in the case of distant earthquakes, in seismograms of horizontal motion, the preliminary vibrations (longitudinal waves) and the maximum vibrations (transverse waves) are generally normal to each other, but for near earthquakes this does not always follow; at times they coincide and at others they may be oblique to, or at right angles, to each other. Actual instances of this have been multiplied several times since the last great earthquake. In horizontal motion seismograms the reason for the transverse waves making various angles with the longitudinal waves seems to lie in the simple fact that the former waves in their propagational path from the origin to the observing station, vibrate in a line perpendicular to the direction of the wave transmission, and in their passage the vibrations may travel, not necessarily in a horizontal direction, but in all directions about a point, according as they are influenced by the nature of the original impulse which set them in motion or by boundary conditions existing in the media through which they travel. Misinterpretations, such as have been pointed out, do not seem to be confined to any one observer, for, in connection with the great Kwanto earthquake of 1923, Dr. Jaggar, basing his observations on my data for Hongo, Tokio, of N 38° W and S 38° E as the direction of the main phase, took a straight line perpendicular to this in determining the direction of the seismic origin. (Bulletin of the Seismological Society of America, vol. 13, no. 1.) Taking the direction of Nagasaki's preliminary tremor as S 30° E, Kumamoto's as S 70° W and Kagoshima's as S 11° E, and combining the three we get the origin as being situated in the neighbourhood of A in the annexed map, Pl. I.

There is next the disagreement with respect to the period of 6.6 sec. as the duration of the preliminary tremor. Our lamented colleague was quite positive as to the correctness of this result, but Mr. S. Maeda, director of the Nagasaki Observatory, doubted it. One of his contentions was that, inasmuch as the durations of the preliminary tremors of the aftershocks ranged from 2 to 3 sec., the duration of 6.6 sec. given for the preliminary tremor of the main earthquake itself was exceedingly doubtful, and that, rather the point where the vibration became somewhat larger ought to have been taken as the boundary line of the two motions, which would then give a result of 3.3 sec. While I am in sympathy with this argument, taking into consideration the preliminary tremor and the direction of the initial phase, I prefer to regard them as belonging directly to the earthquake which took place at 1h 49m 57s in the morning, and as the foreshock of the earthquake which caused the greatest damage to the Simabara peninsula. In other words, I should like to regard these disputed shocks as Twin Earthquakes.

This, in fact, is the conclusion I came to after close examination at Nagasaki of the seismograms covering several days following the severe earthquake. It was found that seismograms of after-shocks, particularly those coming immediately after a big shock, resembled each other fairly closely, whereas in seismograms of the big shocks themselves, the forms of the vibrations preceding the maximum phase showed no similarities, but did so in the succeeding vibrations. This was specially noticeable in the Kagosima seismogram (see Pl. II) in that, with the exception of the biggest shock, the various directions, particularly those running E–W, and the vertical motions showed pronounced similarities in their seismograms. In the case of the vertical motions, they began with large vibrations mostly of about the magnitude of wave no. 19 (see Pl. II), after which it assumed the maximum phase. Compared with these, the seismograms of the biggest shock showed quite different characteristics, consisting of small vibrations at the commencement but gradually increasing in size. What claims our special attention at this stage is the close resemblance between the form of the vibrations immediately following the maximum phase of the biggest earthquake and the form of the maximum phase itself of the second severe earthquake of 11 a.m. The ordinary seismograph at Hukuoka also showed these peculiarities, which for lack of a better name I shall call "two step" motions, meaning that, whereas in the usual order of things a preliminary tremor is followed simply by the principal phase, in this case the order is repeated, that is a preliminary tremor (p in the plate, A) smaller than the same phase of the second severe shock (P in the plate, B) is immedtately followed by another set of preliminary tremor (P in the plate, A) after which come again the two-stepped principal phases (s and S in the vertical seismogram). Further, in the Hukuoka seismogram just mentioned, particularly in the vertical motion, a fairly large vibration follows one second after the initial tremor implying a distinct and separate earthquake.

Now, as just mentioned, if we regard the first big shock as a twin earthquake, then, on the principle that seismic motions due to earthquakes originating from a common source are similar, seismograms taken simultaneously of earthquakes originating from near localities should resemble each other, since, if otherwise, it would be contrary to the principle involved.

Twin earthquakes are not so rare as might be supposed ; we have had experiences of them in the earthquakes that originated at sea off Kasima on the 31st of May, this year ; also in the northwestern part of Kasumigaura and the northern part of Tokyo Bay on the 30th of October last. On the assumption that the severe earthquake as mentioned in the previous paragraphs was a twin earthquake, I have analysed them as follows :—

Station	Difference of time arrivals of P.	Dur. prel. tr. of the biggest shock.	Focal distance.
	sec.	sec.	km.
Nagasaki	3.3	3.6	27
Kagosima	3.3	18.8	140
Hukuoka	1.2	12.7	95

By combining the above results the origin of the severest shock is at a point B, lying to the west of Simabara peninsula in Tidiwa Bay.

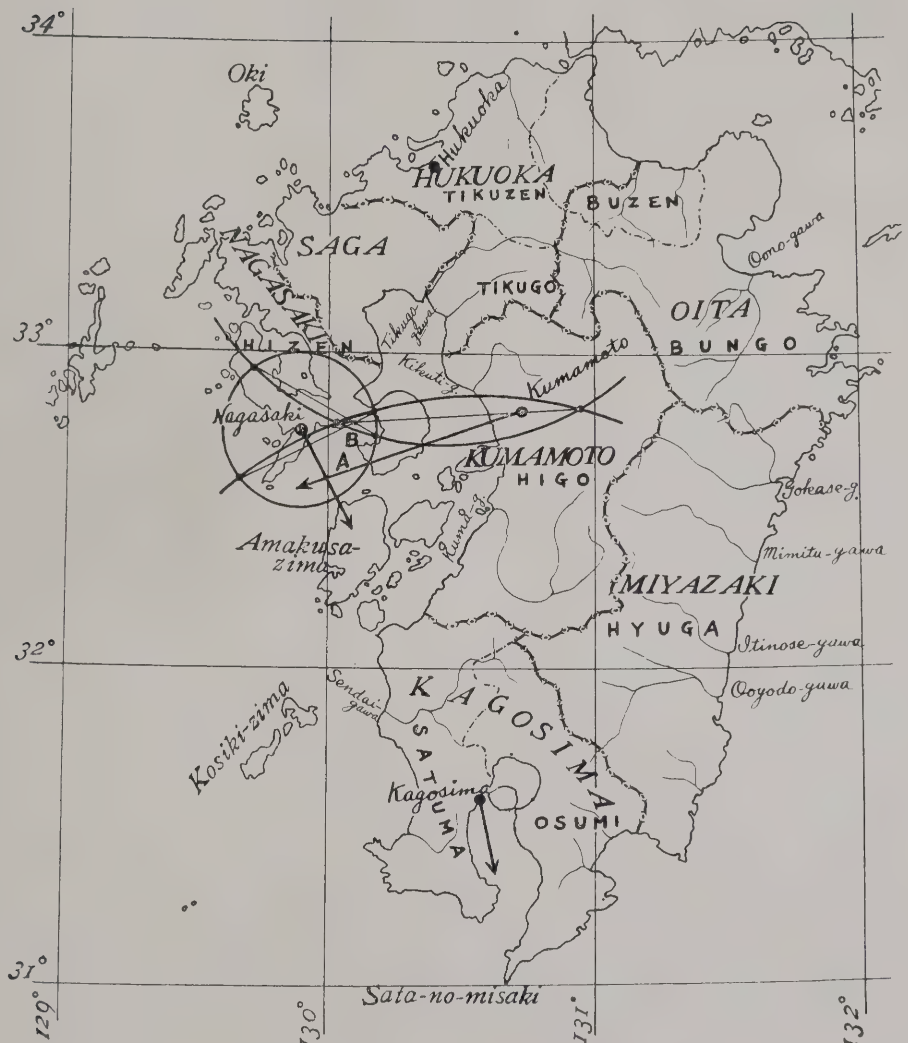
Lastly, there is the disagreement in regard to the relative strengths of the longitudinal waves forming the vertical motion and the transverse motion waves forming the horizontal motion. Our late colleague, accustomed to seismograms of earthquakes with epicentre at some distances away, erred in assuming that the preliminary vibrations of earthquakes, whether originating comparatively near or distant, always consisted of minute vibrations, or "tremors," as the name implies, thus inadvertently introducing errors into his observational results for stations situated in the epifocal area. It is only quite recently that we have had opportunities of studying earthquakes of which Tokyo was the epicentre ; several having occurred this year. In this class of earthquakes it was found that the preliminary vibrations, instead of being a tremor, exhibited the largest vibrations of the entire motion, so that the transverse waves were weaker, or, at the most, equal to it in strength, which simply means that the vertical motions were of a higher order of energy than the horizontal ones.

It seems, furthermore, that inasmuch as the periods of vibration of the longitudinal waves are comparatively small, the energy of the waves during its propagation is rapidly absorbed by the surrounding media, with the result that at a distance away from the origin it is reduced to a mere tremor.

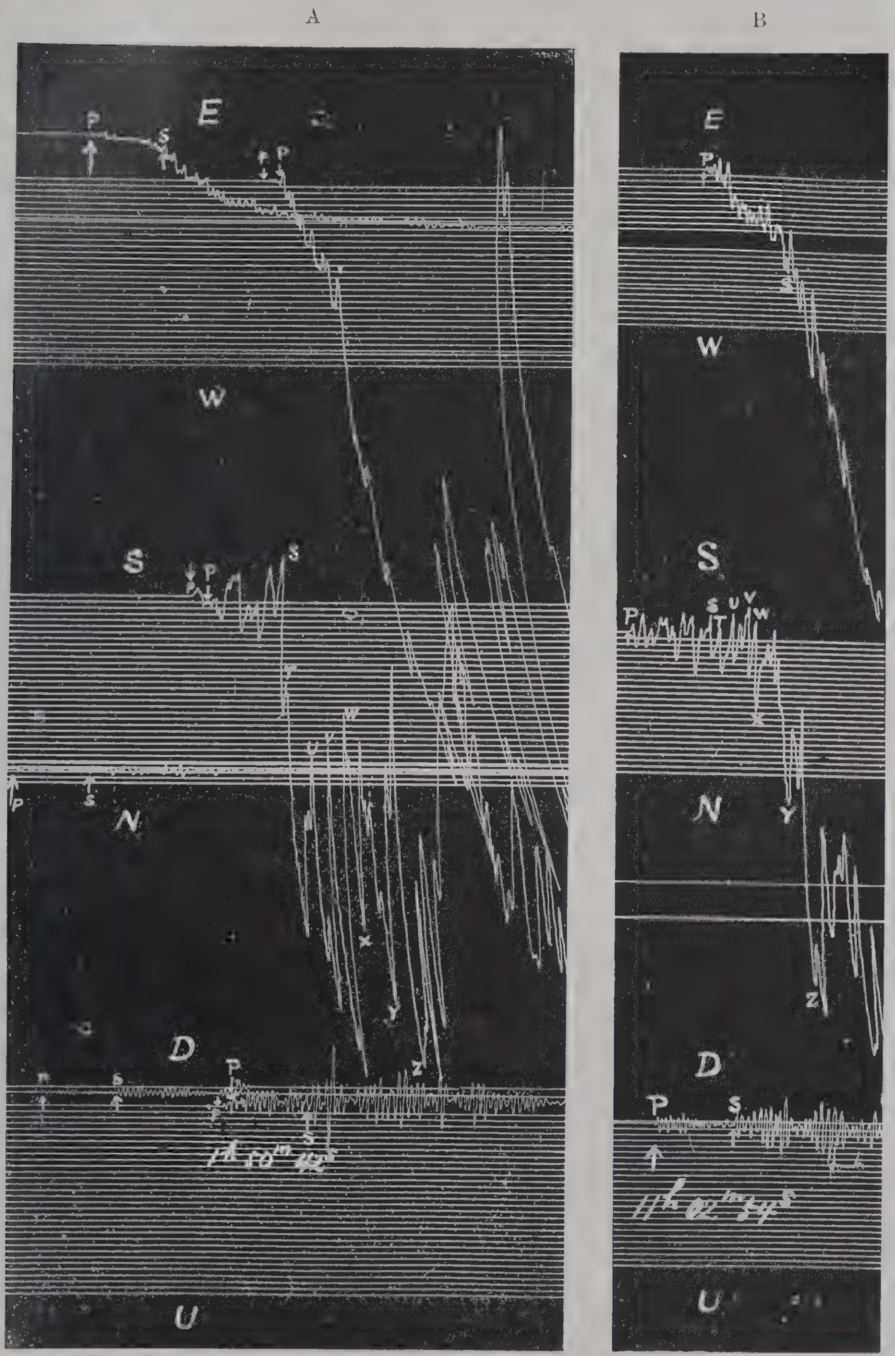
The late Dr. Omori attributed the large displacements by overthrow of simple objects in the meizoseismal area, solely to horizontal motion, but the fact that these large displacements occurring within a limited area all take place in a parallel direction and towards the same direction and never opposite to each other, and also together with the fact that these displacements occur in the same manner at repeated occasions, cannot be explained except as the results of strong vertical motions as well as horizontal. At all events, while the destructive energy of earthquakes at regions situated at distances somewhat remote from the origin may be traced to horizontal motions, for the case of the epicentral regions and vicinity, there are reasons which do not permit us to disregard the effects of the vertical motions as also being a contributing factor.

November 16th, 1924.

Map showing the position of epicentre.



Kagosima observation of the Simabara earthquakes of Dec. 8, 1922, (A) at 1 h 50 m, and (B) at 11 h 2 m.



Statical magnification = 2, time rate = 4 cm. per min.

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TOKYO

October, 1928

The Tazima Earthquake of 1925.

By

A. Imamura.

(*With plates I–XVIII.*)

1. Outline sketch.

The earthquake which shook the northern part of the province of Tazima, lying on the Japan Sea, at about 11 h on the morning of May 23rd, 1925, resulted in the destruction of 3400 houses with a death toll of 428 lives. It was indeed a semi-worldshaker, and of such magnitude that the seismic waves generated were perceptible to seismographs half way round the globe. In marked contrast with this, however, the meizoseismal area was quite small, for on following the lower reaches of the Maruyama river (also called Asago river), it embraced an area no larger than 16 km. E-W by 20 km. N-S. The origin was in all likelihood near the cove of Tuiyama situated at the outlet of this river where it discharges into the Japan Sea, so that another meizoseismal area of equal extent must have extended to the northward of this place.

While the meizoseismal area practically comprised the soft, damp ground forming both banks of the Maruyama river, the region surrounding it consisted of hard igneous rocks and old sedimentary rocks. The two last-named being poor shock-absorbers, acted as favourable media for the transmission of seismic waves, a fact which presumably had no small influence in the distribution of the seismic intensity.

The energy of the vibrations upon leaving the meizoseismal region of soft rocks and entering the hard rocks surrounding it, immediately fell off in intensity, and the isolated patches of high intensity scattered here and there, such as we have been accustomed to associate with the general run of earthquakes, were very few in number. Although the seismic intensity abruptly diminished in its progress in the manner just stated, it maintained thenceforward an uniform rate of energy for a considerable distance. (See Pl. I and II.)

Perhaps the most noteworthy feature of this earthquake is the fact that, unlike in most earthquakes, the meizoseismal area was sharply marked off from the other areas, one of the contributing causes being no doubt the differences in their respective geological characters, that surrounding the meizoseismal area being virtually a barrier wall of granite and liparite.

As shown on Pl. I, there were two centres of maximum destructivity in the meizoseismal area, one in the southern part of it in the town of Toyo-oka and the other in the northern part along the shore of the cove of Tuiyama. In the former the comparatively heavy damage suffered, as shown in the tables annexed, was due to two causes—extremely soft nature of the ground composing the region and the faulty construction of the houses, although as a matter of fact the seismic intensity here ought to have been less than at places situated on the mouth of the river. As to the northern part of the meizoseismal area, whereas in the town of Kinosaki the houses were also of bad construction, the effects of maximum destruction were observed in the village of Tai forming a part of Minato-mura despite the fact that this region is of Tertiary formation, all of which would seem to imply proximity to the origin. Or we might regard it as the epicentre, but in the absence of definite information concerning changes in the adjoining sea-bed, the question will have to be left in abeyance. However, a post-seismic survey of the region has been made by the Naval Hydrographers (Report no. 33, Imperial Naval Hydrographic Dept.), thus providing us with much valuable data for reference and study, but what displacements have been observed were in no case so great that we could hardly deny them as due to probable errors, neither were there any tidal waves registered by the tide-guages so that we will not be far out in assigning the origin to the neighbourhood of the coast along the cove of Tuiyama, situated just at the point where the Maruyama river empties into the Japan Sea. In support of this conclusion we might mention the newly formed Tai fault, and also the manner of distribution of the aftershocks about the region as personally experienced by the writer during his four days stay in the district which ended May 31st. As to instrumental determinations of the origin, those based on records furnished by a few observatories located at no great distance from the affected area, indicated in the main a point quite close to Tai as the likely origin.

TABLE I. Casualties.

Prefecture	Town or village	Preseismic		Burnt houses	Collapsed		Semi-collapsed houses	Damaged houses	Total	Killed	Wounded	Remarks
		dwellings	population		houses	%						
Hyôgo	Toyooka	2,178	11,097	1,483	489	25	30	122	2,124	87	293	Conflagration
	Hatidyô	368	1,910		13	4	42	224	279	2	7	
	Nitta	480	2,449		28	6	121	301	450	1	3	
	Mie	408	2,527		15	4	50	225	290		8	
	Taduno	444	2,311		102	23	118	208	428	8	13	
	Gonosyô	677	3,293		56	8	20	421	497	5	9	Hanya hamlet burnt
	Utikawa	305	1,642		61	10	50	79	190	11	13	
	Kinosaki	702	3,410	548	30	59	10	16	604	272	198	Confiagration
	Minato	813	4,434	148	438	72	142	93	821	33	243	Tuiyama hamlet fire
	Takano	648	3,540		31	5	61	199	291		8	
	Nakasudi	498	2,761	1	8	2	40	254	303		4	Severest in Kaya hamlet
	Nakatakano	405	2,531				11	394	405			
	Kasumi	1.055	6,135					53	53			
	Kutisatu	528	3,326		1		5	368	374			
	Kokuhu	701	3,370		3		23	309	335		4	
	Nasa Sansyo									2	1	
	Total	8.151	42,759	2,180	1,275		723	3,266	7,444	421	804	
Kyôto	Kumihama	458	1,927		20	4	50		70	7	30	
	Total			2,180	1,295		773	3,266	7,514	428	834	

TABLE II. Seismic observations at the different stations.

Station	P or $\bar{P}$ 11h		Dur. prel. tre.	intensity (Mercalli)	Dir. initial phase	Remarks
	m	s	s			
Tokusima	9	06	19	5	S	Sharp, pendulum clock stopped.
Kyoto		44	16	5	NW	Aftershocks, pen. clock stopped.
Toyooka		57		11	S26° W	$\bar{P}$.... 11.0 mm. S, 0.5mm. W.
Niihama	10	00		3		
Tu		02	23	4	W	Aftershocks, vert. mot. pron.
Koti		04		3		
Tadotu		04	22	5	ESE	Gentle.
Yagi		05	25	5	NW	Sharp.

TABLE II (*Continued*).

Station	P or $\overline{P}$ 11h	Dur. prel. tre.	intensity (Mercalli)	Dir. initial phase	Remarks
	m s	s			
Okayama	07	71	4	SSE	
Hikone	08		4		Pen. clock stopped.
Sumoto	09	16	5	SSE	
Hamada	12	35	4	NNE	
Hukui	12	17	4	SE	Pen. clock stopped.
Wakayama	14	20	5	S	Gentle.
Takayama	16	31	0	WSW	
Husiki	16	26	3	SW	Gentle.
Gihu	17	22	3	WNW	Pen. clock stopped.
Sisaka-zima	18		3		
Sionomisaki	19	32	3	SSE or NNW	Gentle.
Turuga	20		4		
Kure	21	34	4		
Kanazawa	27	15	3	SW	Gentle.
Matumoto	28	41	0	SE	
Nagano	30	44	3	ENE	Sharp.
Matuyama	31	33	4	NNE	Gentle.
Iida	36		0	W	
Takata	38	47	0	ESE	
Numadu	39	49	1	SW	
Simonoseki	42	45	0	WSW	Sharp.
Kohu	44	46	4	WNW	Gentle.
Tokyo	45	65	1		
Kumagai	46	53	1	ENE	Gentle, aftershock.
Utunomiya	48	62	0		
Niigata	49	62	2	NE	Gentle.
Tukubasan	50		0		
Maebasi	50	56	0	SW	
Yokohama	51	61	1		
Mera	54	62	0	WSW, ENE	
Mito	57	67	0	ESE	
Nagasaki	59	77	0	WSW	Gentle, aftershock.
Hukuoka	11 00	58	0	W	
Saga	00	81	1		
Miyazaki	02		0		

TABLE II (*Continued*).

Station	P or $\overline{P}$ 11h	Dur. prel. tre.	intensity (Mercalli)	Dir. initial phase	Remarks
	m s	s			
Tyosi	11 05	80	0		
Yamakata	05	82	0		
Kagosima	13	92	0		
Midusawa	17	86	0	NE	

We shall now proceed with the results of our investigations made in the affected area.

Toyo-oka town. Coincident with the earthquake fires started from three different places but fortunately they were easily extinguished. However, two hours later, namely, at about 13 h 30 m, fire starting from an overturned house next door to the post-office spread rapidly and consumed two-thirds of the town, including most of the principal buildings. It is generally held that the reason for the fire having assumed such dimensions was due to the fact that the local fire-brigade after having quelled the first fire, had relaxed their vigilance to such an extent that when the second fire-call came they were quite unprepared for immediate response, thus causing loss of much valuable time. Also the streets leading to the scene of the fire were so blocked with prostrated houses and other debris that traffic was greatly impeded, if not prevented altogether. These circumstances interfered somewhat with our own investigations into the damages caused by the earthquake as apart from the fires. On the other hand fortunately, Dr. T. Matuzawa, Assistant Professor of the Imperial University, Tokyo, in charge of a number of students from the Seismological Institute were on the spot so that full investigations concerning the fires, their origin and extent besides meteorological conditions and various other matters were duly taken in hand by them, as can be seen from their reports already published, so that it will not be necessary for me to dwell on them in this paper. (See Pl. XVI) The action of the Meidi Fire Insurance Co. in promptly despatching an official to conduct full investigations regarding the conflagration on the lines initiated by one of our members, Prof. Seiji Nakamura, at the time of the great Kwanto earthquake cannot be too strongly commended. With the permission of the said company we have incorporated into this report as a supplement, their charts for which favour, as well as for the many valuable and interesting photographs loaned us, we take this opportunity of expressing our sincere appreciations. (See Pl. XVII and XVIII.)

We are thus already in possession of much valuable information regarding the damaged condition of the town of Toyo-oka so that I shall here merely confine myself to a bare description of conditions as I found them.

From a general inspection of the devastated district my opinion is that the proportion of houses destroyed as a direct result of the earthquake was from about one-third to one-fifth of the original total (see Pl. VIII–X). On the street facing the railway station and extending for about five blocks east to west, about 90% of the houses were overturned, and in the case of two-storeyed structures most of the lower storeys had collapsed, leaving the upper storey to fall to the ground quite intact (Pl. IX), the direction of fall always being westwards. This section of the city was formerly a lot of paddy fields recently filled in with some five feet of earth, hence newly made ground, which fact was responsible for the heavy damage, but what contributed still more to it was the very defective construction of the houses. In looking over the ravaged areas a noticeable feature was the preponderance of destruction on the streets that ran in an E-W direction, especially so in the newly made ground above mentioned, whereas in the streets which were at right angles to them, the damage suffered was much less notwithstanding the fact that many of them stood on soft ground. This led to the current belief that the earthquake moved in an E-W direction. From my own investigations the direction of the main phase seemed to be from W by N to E by S or from WNW to ESE, so that there would seem to be a modicum of truth in the popular idea, but in settling this question it behoves us to take first of all careful note of the general method of house construction in vogue in this section of the country. Pl. X, Fig. 3, shows a house that was being built at the time of the earthquake and which might be taken as typical of the manner of construction in vogue. In the building of these houses, after the supporting pillars have been placed every meter apart for each of the right and left hand side walls, ties are run through them horizontally also a meter apart, then strengthened by small wedges and the whole then plastered over, but for the sides at right angles to them (one of them, the back, is seen facing us in the photograph) there is no pillar at all between the two end corner posts.

Obviously such a structure will offer considerable resistance to a shock coming in a direction parallel to the protected walls, but they will be positively at its mercy should the motion come from a direction at right angles to them. In the latter case the resistance will probably be no more than one-tenth of that in the former. It follows then that houses so constructed are safe for earthquake motion in one direction only, but dangerous when it comes from a direction perpendicular to it so that they are not earthquake-proof.

Now since the earthquake motion was practically in an E-W direction, houses, which faced the streets running in the same direction, obviously had their protected walls perpendicular, and their unprotected walls parallel, to the direction of the street and consequently with the earthquake motion, with the result that much damage was suffered, whereas houses facing streets that ran in a N-S direction escaped with little or no damage. However, even in the case of houses of the former class, those that had several supporting pillars in the interior partitioning walls in an E-W direction withstood the shock as in the case of the one seen left standing in the foreground of Pl. X, Fig. 2.[1] It should also be noted that with houses facing streets running N-S, although the walls that were parallel to the longer axis of the house suffered no damage, those forming the shorter axis were in several instances put out of plumb.

Kinosaki. This town is a watering place situated along a small valley of Tertiary formation and has six thermal springs in a line with the river course. Of its 700 houses a large number were hotels, mostly three-storeyed with a sprinkling of four-storeyed buildings. While the houses built directly on local rock free of loose surface soil were not so affected, those built lower down on comparatively soft ground following the river course collapsed mostly at the junction of the first and second storeys with the upper storey intact, so that two-storeyed houses became one-storeyed and three-storeyed houses became two-storeyed as shown in Pl. XI, Fig. 3 and 4. Under these conditions fires naturally broke out from a number of places. With the big shock it started from five different sources which soon after increased to eight. Flying sparks and cinders helped to spread the conflagration, and within about four hours the major portion of the town consisting of 548 houses was laid waste with a casualty list of 272 lives. Pl. XI, XII and XVII will

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1) Although not shown in the photograph, this particular house had several pillars in the required direction in the partitioning walls in the interior of the house, so that it was saved.

help to convey some idea of the havoc wrought, not even forests escaping the ravages of the all-consuming fires. The proportion of ruined houses as a direct result of the earthquake, however, does not seem to have exceeded 50% of the original total as an examination of Pl. XVII. An idea of the appearance of a house escaped from a fire can be gained by comparing Pl. XI, Fig. 3 which was taken before, with Fig. 1 of Pl. XII taken after, the fire on May 29. Although I took up my headquarters on the second floor of the abandoned Kinosaki Hotel, there were several other buildings temporarily abandoned but which could well have been used as a makeshift.

Momosima is a hamlet situated on the other side of a hill forming the northern boundary of the spa town of Kinosaki, with the greater part of itself built on a filled up swamp. The damage here was unduly heavy with even a case of a house that shifted bodily from its foundation (Pl. X, Fig. 4). Not very far from here a portion of a railway track subsided, causing temporary suspension of traffic, but all railway damages were repaired with amazing alacrity so that by midnight of the eventful day traffic on all the lines were functioning. The loss from damages within the compounds of the two stations of Kinosaki and Toyo-oka, including that of the station buildings, was estimated to reach *Yen* 200,000, the comparatively small damage being largely due to their having been situated on hard ground.

There were rumours to the effect that the hotsprings of Kinosaki had undergone changes, so in order to verify them I made personal examinations of the springs at 17 h on the 29th of May and obtained the following results:—

Dizo-yu	(spring)	49°.0C
Itino-yu	,,	59°.6
Mandara-yu	,,	59°.8
Kôno-yu	,,	48°.6

which being their normal temperatures, no changes have taken place, a most fortunate thing indeed for this town and which will largely determine its future reconstruction possibilities.

Minato-mura. As this group of hamlets was in the epicentral region the damage caused by both earthquake and fire was very great as can be seen from Table III. At Tuiyama, one of the hamlets, the northern part of it comprising more than a half of the entire hamlet was wiped out, leaving intact only a new temple that was in course of erection (see Pl. XVIII). In the central part of this hamlet about a quarter of the total number of houses were either shaken down or else badly damaged, while in the southern section there was an equal proportion of houses damaged, although very slightly. At the hamlet of Seto, also, despite the hard nature of the ground, the damage was very great, particularly so at the Kôsai primary school (Pl. XIII, Fig. 1 and 2), where a beam at the entrance of the building fell and crushed a boy to death. On the left hand side of Fig. 2 in the same photograph is shown the roof of a sheltered playground, which also fell in and crushed five young people to death. The chief causes underlying the heavy damage to the school have been treated by Mr. Taniguchi (report in Japanese), but what arrested my attention when I visited the spot was that a portion of the space covered by the school building was newly made ground where an earth-fissure had formed running right underneath the building. When this fissure opened it naturally tore the building asunder. There were also constructional defects in the building itself with simply aggravated matters. As to the southern wing of the building which was left standing, we found that it was resting on rock without the usual mantle of loose soil, and where we could not detect a single earth-crack. Thanks to the good material employed in this part of the building the only effect of the shock that we could discover was a slight canting of the building towards the north, but as its ability to withstand aftershocks was apparent, our party did not hesitate to spend a night on the upper floor. As to the aftershocks that were felt here by us that night, and also on the following morning, they will be taken up in a later paragraph.

The village office of Minato-mura is shown in Pl. XV, Fig. 4 and is a substantially built ferro-concrete structure, such that it was claimed to be a model of what such offices in Japan should be. Beyond a few insignificant cracks on the walls the building came through the severe ordeal quite unscathed, with the result that in the days immediately following the earthquake it was utilized considerably by various investigation parties and others, but the undignified action of these people in scampering pell-mell out of the building on the occasion of every aftershock, thus augmenting the then nervous tension of the ignorant populace, was very thoughtless to say the least.

Tai. In this hamlet 82 out of a total of 83 dwellings were thrown down, leaving unharmed only a two-storeyed Young Men's Club building. There were left standing, besides, a warehouse and a temple, but all the dwelling houses proper were demolished (see Pl. XV, Fig.

TABLE III. Casualties in Minato-mura.

Hamlet	Population	Dwellings						Killed	Wounded
		total	burnt	collapsed	semi-col.	damaged	col. %		
Kozima	390	83	0	23	52	6	28	1	5
Seto	574	116	1	48	53	14	41	4	33
Tuiyama	1377	250	145	68	37	0	85	19	82
Kei	1129	191	2	92	*70	27	85	6	15
Tai	494	83	0	67	*15	1	99	7	46
Hatakami	317	59	0	10	*24	25	57	0	0
Mihara	153	31	0	1	*20	20	68	0	0
Total	4434	813	148	309	271	93	72	37	182

* Repair incapable.

1 and 2). Unfortunately, it was the season for rearing the silkworm with the result that the inmates of 36 of the houses were making use of charcoal fires for the purpose, so that immediately after the big shock, fire broke out in three different places, while smoke was seen to be issuing from several others. At the same time pitiful cries for help could be heard coming from several quarters from underneath the fallen beams and other heavy material, but those who were able got together and promptly set to work to put out the fires before attempting any rescue work. After the fires had been put under control attention was concentrated on the extrication of the unfortunates pinned under the fallen buildings, whereupon 58 out of a total of 65 persons were saved.

In the case of most earthquakes, after a preliminary tremor lasting from 7 to 10 seconds comes the big shock, but at Tai the preliminary tremor lasted only a second or two, or three seconds at the most, which helps to confirm the report that these seven who were killed were found to have died in the very act of their occupations, in other words death was instantaneous owing to the suddenness of the principal shock. Now, since the greater the shock the greater is the casualty proportion likely to be, credit for this small casualty list must be given to the wisely directed efforts of the inhabitants in first fighting the fires before undertaking rescue work, for if the fires had been allowed to hold full sway, as was the case at Toyo-oka, Kinosaki and Tuiyama, the death-list would have been far greater, to say nothing of the inevitable heavy losses in property. If on the other hand these good people had reversed the order of things and taken up rescue work first, their success would have been limited, since much time would have occupied the work of rescuing the people imprisoned under fallen roofs, beams and such heavy material, so that hardly before anything could be accomplished the fires would have rapidly advanced and swept everything before them. For the poor unfortunates a little delay in rescue would have been nothing compared with the deadly fire peril. This experience drives home to us in an eloquent manner the importance, in the event of a destructive earthquake, of first fighting the fires before proceeding with the rescue work, as a step towards reducing the casualties to a minimum. To show how well the people of Tai were provided in the matter of fire control, we learnt that there was even a female fire-corps equipped with a gasolene fire-engine. Obviously, it is only with such ideas and equipment on the part of the citizens that earthquake emergencies can be met in a proper and efficient manner.

It was in this region that the so-called Tai fault (Pl. I and XIV) was discovered, and in regard to which I shall make only a few remarks, referring the reader to Professor N, Yamasaki's valuable paper following the present report.

The fault is on the top of a hill, the highest part of which is 231 meters, and lying to the north of the village of Tai. There were formed two fault lines almost parallel to each other and running in a direction SW to NE for a distance of nearly 1500 meters, the distance separating the two being about 400 meters at the widest part. A view of the hill as seen from Tuiyama is reproduced in Pl. XIV, Fig. 4. The spot on the hill where a landslide occurred forms one end of the fault line, and Fig. 1 and 2 show where the western fault line traverses a grove of willow trees, the making of willow wicker baskets being an important industry here. While the vertical dislocation here was only 20 cm. and the horizontal shift (the western side towards the south) not more than 6 cm., there were places where the vertical shift, or throw, was as much as 1 meter. Fig. 3 is a continuation of the same pictures and shows the formation of a trench, the spot in the middle of the picture where a man is seen standing being the central part of the rift.

Some ascribe this dislocation to a mere surface movement but my opinion is that it is deepseated, as will appear in the next paragraph.

The hamlet of Kei suffered almost next to Tai, the loss being 161 houses out of a total of 191 with six persons killed. Here also fires broke out but with the aid of a gasolene fire-engine they were put out after two houses had been burnt down. From reports received later, it seems that very conspicuous earth-fissures were noticed at a place lying southwards of the primary school, and that for several days following the great shock warm water was being ejected from these fissures. The fact that these cracks were in a direction parallel with the Tai fault lends strong support to our conclusion that they were a continuation of the fault.

Kumihama. This is a town in Kyoto prefecture, and as is shown in Pl. XVIII, Fig. 2 destruction was confined almost to the central part of the town, particulary the soft grounds forming the river banks, but considering that it was distant only 8 km. from the epicentre, the damage sustained was small, being only 4% of the total. By the time the seismic energy had reached this place much of it must have been dissipated, but an interesting phenomenon in connection with the earthquake left its record in the sinking under 7 feet of seawater of a paddy field and a mulberry patch that were on either side of the mouth of the Kadurano-gawa, a stream discharging into the northeastern end of Kumihama Bay (see Pl. XV, Fig. 3). The area of these two fields was 25 acres, and while at some places the overlying depth of water was as much as 7 feet, the average depth was about 4 feet. These two spots were however nothing more than a sort of delta formed by deposits of soil and sand which had been accumulating for the last 10 years, and being only loosely held together, the earthquake simply shook them off so that they slid into the sea. Of almost equal interest was the production of a *seiche* in the northern half of the bay, brought about by the slipping of the two fields just described and resulting in waves as high as three to four feet.

Takano. This town is situated at the same distance westwards from the epicentre as Kumihama is situated from it eastwards and with pretty much the same proportion of houses thrown down. What claimed our attention here was the displacement made by the main sanctuary of the Takano shrine the shift being 16 cm. in a direction S 62°E.

Another interesting thing here was the yielding of a girder of the wooden bridge spanning the Takano-gawa river (Pl. XIII, Fig. 3). According to the village office people, one of their officials was just crossing the bridge when the girder gave way, whereupon he instantly ran for his life to the opposite side of the river, upon reaching which he found to his astonishment that the earthquake had already ceased completely—another proof attesting the extraordinary suddenness with which the big shock came and as suddenly went away.

2. Measurements of the earth-movements.

Although in most countries, including our own, observational methods for the rapid motion of distant earthquakes are in a fairly advanced stage of development, those for the fundamental slow motions of the same class of earthquakes, or for near earthquakes for that matter, do not seem to be receiving the attention they deserve at the hands of investigators. Personally, I cannot help deploring the unsatisfactory character of the seismograms of the recent earthquakes as obtained at various stations situated close to the scene of the disaster. The Osaka station possesses an Omori seismograph with which good records were obtained (Pl. V), but owing to instrumental defects the natural free vibrations of the pendulum are found to be mixed up with the preliminary tremors, so that to determine the actual ground movements is extremely difficult. In these circumstances the only course open is to confine our analysis first to such records, the comparative correctness of which we are reasonably certain, and then go on to the actual ground movements which took place at Osaka.

The Tokyo observations. At the Seismological Institute very valuable records were obtained with a horizontal seismograph having a self-vibration period of 33 sec. E-W and 30 sec. N-S and a magnification of 1.5 times. To this we have added the record given by a vertical component seismograph with a self vibration period of 12 sec. and magnification 20 times, the three traces being shown on Pl. III. We had, besides, two instruments with a self vibration period of 10 sec. and magnification 2 which gave fairly good results (Pl. IV), but soon after the commencement of the main phase rather large undulations crept in, thus proving imperfect damping and the necessity for considerable corrections. However, even were we to make the required corrections, it is necessary that we firstly consider the 1.5 times seismogram, the details of which are as follows :—

Magnification=1.5 times; time of commencement=11 h. 10 m. 49 sec.; duration of preliminary tremor=61 sec.; total duration=30 min.

The E-W motion.

Period of P	=10 sec.	Amplitude (a) of P	= 0.2mm. W
do. S	= 3.1 sec.	do. S	= 0.8mm. E
Period of most intense phase (E)	= 3 sec.	Double amplitude ($2a$)	= 7 mm. E
do. L	=13 sec.	do.	= 4 mm. E
do. M	= 8 sec.	do.	=14.8mm. W

The N-S motion.

Period of P	=10 sec.	Amplitude very slight.	N
do. S	= 4 sec.	do.	= 0.8mm. N
do. most intense phase (E)	= 3 sec.	Double amplitude	= 3.6mm. N
do. L	=14 sec.	Amplitude	=14 mm. N
do. M	= 8 sec.	do.	=14 mm. S

The resultant wave.

Direction of P by tromometer=E upwards.

Period of most intense phase (E)	= 3 sec.	Double amplitude	= 7.9mm.
do. M	= 8 sec.	Amplitude	=20.4mm.

The vertical motion (Diagram 3).

P=upward motion.

Period of most intense phase (E)	= 3 sec.	Double amplitude	= 2.6mm.
do. M	= 6 sec.	Amplitude	= 3.8mm.

Results from 2-time mag. instrument (Pl. IV).

Period of P		Amplitude of P	
do. S	= 4 sec.	do.	S=0.9mm. E; 0.8mm. N
do. most intense phase (E)	= 3 sec.	Double amplitude	8mm. E; 3mm. N; (resultant wave 8.8mm.)
do. M	=12 sec.	do.	23mm. E (resultant wave 31mm.)

In the 2-time mag. record above, the vibration periods of S, E etc., when compared with the free vibration period of the pendulum, is less than one third of that of the latter and by comparing same with the record of the 1.5 times seismograph, we see that it closely approaches the actual ground movement, thus rendering any correction unnecessary, but as the period of the M waves approached very closely the natural vibration of the pendulum, resonance effects were set up. Now assuming the earthquake motion to consist of sinusoidal waves, and introducing a correction for the resonance phenomenon with ratios of amplitudes of consecutive phases, the values of which are 2.17 and 1.97 in the E-W and N-S components respectively, then the amplitudes of the M phase in the E-W and N-S components together with that of their resultant come out as 11, 13 and 17 mm. The results thus obtained are very near those given by the diagram of the 1.5-time seismagraph.

The Osaka observations. (See Pl. V.) These were made by an Omori seismograph (natural size) having a free vibration period of about 4 sec. Details are

Time of commencement=11h. 10m. 4.4 sec.; duration of preliminary tremors=14.8 sec.

P. Towards W 0.7mm.; N 2mm.; downwards 0.5mm. Between *a* and *b* the natural period of the pendulum has twice obscured the traces of the actual ground movement, which fact can be confirmed by comparing the diagram with that of the aftershock of May 26th.

S. On the large natural vibrations, *c*, *f* and *g*, of the pendulum may be seen superposed the main phase movement which has made two complete swings back and forth.

The first wave $\bar{s}cd$—23mm. W; 8mm. S. Next 37mm. E, 3.5mm. N.

The second wave *def*—15.5mm. W; 8.5mm. S. Next 33.4mm. E, 27.5mm. N.

From here onwards the pendulum's own free vibrations cannot be disentangled from the true motions of the earth particle. From the foregoing data we have deduced the followning elements:—

Direction of the initial tremor=N 20° W.

Double amplitude of the maximum earth-movement (assumed to be *cd*) =37mm. with a period of 1.6 sec. and direction E by N.

Although results of observations of the initial severe shocks are as above, those of the aftershocks made at the various stations were more satisfactory, especially those of Prof. Shida of the Kyoto University made with his new sensitive seismograph of 20,000 times magnification, which in a very brief interval recorded as many as 12,000 aftershocks. There are, besides, observations from the stations of Toyo-oka, Kobe and Osaka which we have tabulated in order to facilitate comparisons, and which will be found as an appendix to this report. I wish now to take this opportunity of sincerely thanking all those who so kindly sent us their observations. Although a note of dissatisfaction was sounded in an earlier paragraph concerning the seismogram that was sent us by the Osaka observatory, I should like to explain that the complaint had reference to the inefficient condition of the instrument and not with the members of the staff there, to whom, in particular, I feel bound to convey my appreciation of the good work done in spite of the handicap of a defective instrument.

When contrasted with the great Kwanto earthquake, the present one showed some distinct peculiarities, the outstanding one being the unusual short duration of the shaking. In the vicinity of the epicentre the duration perceptible without instrumental aid must have been about 20 sec. As for the duration of the preliminary tremor, around Kinosaki it was most likely some seconds, but at Minato-mura it could not have been more than from one to two seconds or at the most three seconds. For the main phase, the one that causes the destruction, it seems to have been a matter of only one or two complete swings back and forth. Actual experiences at the primary schools of Kei and Seto seem to bear out these conclusions. There is also the experience of the village official as already described, who on running for his life from a bridge whose girder gave way, to the opposite bank of the river a distance of 40 meters, found on his arrival there that all motion had completely stopped.

As regards the intensity of the earthquake, observers are practically unanimous in the opinion that in the vicinity of the epicentre it must have been about 40% of the acceleration due to gravity, but as to the period, or the amplitude of the said motion, there is a diversity of opinion. To take one example, there is Dr. Suda's figure, based on the personal experience of Mr. Yamazaki, Director of the Toyo-oka observatory, as well as on records of aftershocks, and from which he deduces 0.2-0.3 sec. as the period of the maximum phase. While I do not in the least question the verity of the said personal experiences, nor that of the observations of the aftershocks, I am sorry that I am compelled to admit difficulty in accepting this particular motion that has been considered by him as being the main motion which was responsible for shaking down buildings, those wooden ones that stood from two to four storeys in height, and as this question is an important one from the standpoint of practical seismology I shall discuss it fully.

Up to now there have not been many earthquakes in which the ground movements at or near the epicentre were measured by instrumental means. For Tokyo, we have had some two or three examples, but in none of them did the main phase, which is the motion that causes the destruction, have a period of less than from about one second. We find this exemplified in the case of the Tokyo earthquake of June 20th, 1894; in the Ryugasaki earthquake of Dec. 8th, 1921 (Pl. VI); in the Uraga Channel earthquake of April 26th, 1922 (Pl. VII), and finally in the great Kwanto earthquake of Sept. 1st, 1923. But even in these we shall find superposed on the main phase waves, small waves (ripples) which we might call "harmonics," but which ought not to be ignored. Turning our attention to the seismogram of the Uraga Channel earthquake selected for elucidation, the main phase shows a double amplitude of 59mm. with a period of 1.4 sec., but in addition to this, there is seen following it for an interval of some 10 seconds, a small wave having a total amplitude of 7 mm. and a period of 0.8 sec. This record was rejected by the late Dr. Omori as being imperfect and unreliable (Seismological Notes, No. 3, Art. 11) although I must confess inability to see anything the matter with it, for on comparing it with the diagram obtained by the Tanakadate strong motion seismograph (loc. cit., Pl. III, Fig 4) its trustworthiness is quite apparent. In our next example, the Ryugasaki earthquake, we find another important thing. This earthquake in its E-W motion registered 34mm. for its double amplitude in one single wave of period 3.6 sec., whereas in the N-S motion during the same interval, two waves are shown, which is to say that whereas for the first and second waves the double amplitudes are 29 mm. and 12 mm. respectively, the periods are for either case one half that of the corresponding E-W motion, namely 1.8 sec. These horizontal motions compounded give a parabolic curve as per diagram in Pl. VI. Possibly, doubts may be entertained as to whether or not this difference of periods in both components is, as in Melde's experiments, due to errors arising from natural vibrations inherent in the instrument, but when contrasted with the period of this motion, not only is the natural period of the seismograph three times that of the earth's vibration of 3.6 sec., but the record from a horizontal pendulum with a free vibration period of 30 sec. (Seism. Notes, No. 2, Fig. 5) is just the same as the register obtained with this instrument of 2-time magnification and period 10 sec., so that it does not seem as if the difference in periods in both components can be accounted for by any instrumental peculiarities. For this earthquake, besides the foregoing, there is recorded for several seconds following it, another small wave of double amplitude of 4 mm. and a period of about 0.8 sec.

In large earthquakes like the preceding the amplitude of the small wave, or ripples, is comparatively small, but as the earthquake diminishes in strength the period of the fundamental wave also diminishes. On the other hand, the small wave that is superposed on it becomes more and more pronounced, so that eventually the fundamental wave is recognised only with difficulty. Under these conditions the period of the main phase of a small earthquake becomes reduced to the order of one second or thereabouts.

As the probable reason for this I venture to submit the following:— In any earthquake the fundamental waves, together with their harmonics, are propagated from the focus, but the period of the former varies with the energy of the original impulse, and also with the extent or size of the block regarded as a vibration-generator. These variations would also seem to determine whether the harmonics shall be monotonic or otherwise. Leaving aside the question of whether or not we are justified in our interpretation of the seismograms, it must be said that the majority of the actual cases that have been studied have led us to the foregoing conclusions, therefore, in the case of the Tazima earthquake we cannot very well take the period of the maximum phase of a small aftershock as the period of the maximum phase of the initial severe shock. As being appropriate to the preceding discussion a table is here added, in which are compared the observational results at Osaka and Tokyo of the initial severe shock of the Tazima earthquake, together with those of the aftershocks of May 26th (see No. 88 in the list of aftershocks appended) and June 23rd., and from which can be seen the magnitudes of these three earthquakes and the periods of their maximum phases.

TABLE IV. Comparative view of the seismic observations at Osaka and Tokyo.

Date	Osaka (distance 125 km.)		Tokyo (distance 460 km.)	
	Double amplitude	Period	Double amplitude	Period
	mm.	sec.	mm.	sec.
May 23	37.0	1.8	10.4	3.0
May 26	6.1	1.2	0.18	1.8
June 23			0.054	1.6

According to this table the period of the main phase as registered at Tokyo is nearly 50% greater than that of the corresponding phases registered at Osaka, the explanation of which would seem to be that in the transmission of the earth vibrations those of quick period were quickly absorbed by the intervening medium, thus rendering its traces on the diagram almost illegible. Furthermore, in the Osaka diagram of the initial big shock, attention is drawn to the small waves with a period of 0.8 sec. which are distinctly seen following the S-N motion *cd*, E-W motion ff' and the vertical motion *c*. Perhaps these small oscillations are characteristic of the Osaka region, but seeing that waves of such a period can be noticed quite prominently even in the preliminary tremor, I am still inclined to regard them as nothing more than waves propagated from the seismic focus.

As motions causing the destruction of fairly tall buildings in the epifocal area we might mention firstly the wave of period 1.8 sec., although, I presume that the small wave of period 0.8 sec., together with the one of 0.2-0.3 sec. that was felt by Director Yamazaki, did really exist and that they showed their effects as well. Needless to say, we cannot very well consider the period alone independent of the amplitude, but taking for granted that the acceleration as deduced from the period and amplitude is an invariable quantity, it may not be unprofitable to see what will result as a change in the period. Assuming the seismic intensity to have been 40% of that of gravity, then the amplitudes for periods of 0.2 or 0.3 sec. work out to 4 mm. or 9 mm. Such a small but quick motion might overturn cylindrical objects of small height, or cause small cracks in walls. It might also be felt as a fairly strong shock by the unaided senses. But their effect on objects having larger natural periods of oscillation of their own would probably be very much less. For this reason I have an apprehension that an error has been made in the conclusion that the main phase responsible for the destruction was the wave of period ranging from 0.2 to 0.3 sec. as personally felt by Director Yamazaki.

In the first earthquake there were no cases observed of large displacements made by simple-shaped objects. The most conspicuous one did not show a greater shift than 5 or 6 inches. (Pl. X, Fig. 4.) This would seem to suggest that there was no motion sufficient in either strength or amplitude to cause large displacements, nor a repetition of shocks that were violent but of smaller amplitude. On the other hand, while the magnitude of the shocks was on the whole on a small scale, so long as any objects were displaced we should be able to recognize the effects of the horizontal motion where it overcame the frictional forces during the instantaneous interval.

It would seem that in and around Momosima the seismic intensity was something like 40% of gravity, so that were the acceleration of the vertical motion to operate against gravity at the instant, we could readily imagine objects displaced instantly or by a succession of rapid motions. However, the amplitude of a motion with period 0.2 sec. and an acceleration 40% of g is not likely to be much over 4 mm., hence, as already mentioned, not only is it difficult to suppose that such a small horizontal movement can be responsible for the overturning of tall wooden buildings, but it does not even seem sufficient to explain the phenomenon of small displacements. Since, moreover, the vertical motion of such quick-period waves in working against gravity is very liable to produce displacement, then at places like Takano situated close to the origin, it was probably responsible for the small displacements cited, notwithstanding the fact that the intensity of the horizontal motion was no more than about 20% of gravity.

In concluding our remarks on the nature of this earthquake motion, attention is called to the phenomenon of stationary waves exhibited by the mud stratas of the lower part of the Maruyama river, and also on both of its banks. These were gravity waves due to the earthquake motion having acted similarly to water that is confined in a vessel. The area affected by this earthquake being longer in the N-S than in the E-W direction, and as the direction of the main phase was likewise in a nearly E-W direction, there was a nodal line along the middle part of the river basin parallel to the banks, while along both banks stationary waves with loops could be observed. As a consequence of this we should expect to see phenomena resembling inundation at the river shores, and this is what has precisely happened, it being traceable in the paddy fields either as surface undulations or as earth cracks ejecting mud and sand in such a manner as to confound at times the investigators who were in the neighbourhood trying to discover faults.

3. The seismic origin.

As stated in an early paragraph, the distribution of the earthquake intensities points to either the cove of Tuiyama or its vicinity as the origin. Taking this place as the centre, a reduction of the results of observations of four near stations brings us practically to the same conclusion, but, unfortunately, the fact that these observations do not include one from a station situated in the north, somewhat discounts their value. The question then arises as to whether or not we ought to take for the epicentre a locality some kilometers north of Tuiyama, which in any case is not likely to exceed 10 km., and to obtain which accurately, we have available the distances computed from the durations of the preliminary tremors from seismograms of the above four stations. An alternative method is to determine it from the directions of the preliminary tremors, but the objections to both of these methods is that seismic waves are not transmitted in anything like an orderly or regular manner. In the unavoidable circumstances the writer, in his quest for the seismic origin, had to rely on his own personal observations of the aftershocks during his four days sojourn in the shaken districts, and which will be found arranged in Table V below.

Tables V. Aftershocks felt by unaided senses.

Date			Aftershock no. in Appendix	Duration prel. tre.	Azimuth earthq. sound	Intensity	Place of observation
d	h	m		sec.			
27	16	35	181	3	NNE	weak	Momosima
28	21	38	—	—	E by S	slight	Seto Prim. school
29	00	16	208	—	E by S	do.	do.
29	07	39	214	1	E	strong	do.
29	12	30	218	—	S 60° E	slight	Kanzui
29	17	49	222	—	N 60° E	do.	Kinosaki
30	06	07	—	3	NE	do.	do.

As nothing more than a compass and a stopwatch was used in the above observation, the scientific value of the results are obviously open to question, but in anticipation of contingencies like the present, the writer has been using this seemingly rough and ready method for some time, always comparing them afterwards with the instrumental results, until by dint of practise a stage of proficiency has been reached, whereby, as in the case of the preliminary tremors, the errors are invariably within 10% of the true results. As for the earth sounds or rumblings, since the apparent direction of the origin as indicated by these sounds do not always accord with the actual origin owing to topographical irregularities, only those that were heard on plains or level ground have been considered. Out of the seven listed above, the one heard at the Kôsai Primary School in the early morning of the 29th had especially to do with the shock that violently shook the already partly demolished school-house. This shock was strong enough to alarm some of the members of our party who passed the night on the upper floor of the partly ruined school-house. The writer was however able to experience it outside of the building on level ground. Since the severe aftershock of the 26th, this one, in the opinion of many, was the strongest felt, and that in all its features, from the earth-sound down to the main-phase, it was a faithful repetition of the initial violent shock.

At Tai and Kei the duration of the preliminary tremor was only a matter of one or two seconds, or three seconds at the most, whereas at Kinosaki and Takano it was barely three seconds. The reason why, as in the above list, the preliminary tremors could not be noticed was that either they were too weak to be sensible, or that they did not exist. The accuracy of observations made on the third night may be questioned on the score of physical strain and fatigue on the part of the observer through lack of sleep, but it is well to explain that in investigation tours like the present, the writer generally manages to do with little or no sleep for days, keeping strict vigil with compass, watch, candles and matches so as not to allow the slightest phenomenon to escape unobserved, with the result that such observations are likely to be more accurate than those made in the day time.

By collating the foregoing aftershocks with the observations made at Toyo-oka, we get the origin as being near the eastern shore of Tuiyama cove, or rather about where the Tai fault made its appearance. However, the focus from whence originates the aftershocks is not always the starting point of the initial severe shock, but if the latter were really situated a little distance off the cove of Tuiyama, then it would be legitimate to expect aftershocks in that vicinity, so that during the four days of our sojourn aftershocks should have visited that region. Again, as has already been stated, there are observers who hold that the aftershocks of the 29th behaved similarly to the initial severe shock, which goes to strengthen the writer's conviction that the latter had its origin in the Tertiary block forming the right hand shore of Tuiyama cove, in which case the intimate relation between the origin and the Tai fault becomes obvious. It would then also accord with the sound directions of the initial severe shock found for various places, namely, NE for Toyo-oka; NW for Kumihama and Mihara; W for Tai and Kei and E for Takano and Kasumi.

The foregoing data for the estimation of the seismic focus naturally apply to that of the focal depth as well. Personally, the writer is in favour of taking the depth as being under 25 km., say, about 10 km., which would then be in accord with the intensity distribution. On the latter assumption the focal distance from Takano or from Kumihama will be equal to the focal distance from Tai or from Kei increased by 30%, in which case the notable disparity in the seismic intensities referred to previously become explainable. If, on the other hand, we take the depth as, say, 40 km., then the distances from the places just mentioned to the seismic origin will practically be the same, but we shall then find ourselves in a dilemma since this would argue practical uniformity of geological structure for all the places mentioned, in which event the disparity in the seismic intensity distribution would remain unexplained.

In the present discussion when the focal depth is considered in connection with the duration of the preliminary tremor as basis of computation, then the term seismic origin means the point of propagation of the seismic motion, but when it is considered from the standpoint of intensity distribution, then it refers to the centre of the area where the seismic force is being generated. When the seismic force is very great we must consider the two as separate and distinct, but if the shock is slight and is more or less of a local character there is no harm in treating them as the same. Dr. K. Wadati, who investigated the depths of the seismic focus and the layer of discontinuity from the transmission curves of the $\overline{P}$ and P phases of the present earthquake, estimated the focal depth at 33 km.[1] The discrepancy of the data on focal depth thus worked out may be due to the difference of foci dealt with. We might also add that while with earthquakes of inland origin, as distinguished from those of submarine origin, the focal depths in the majority of cases seem to be in the order of 40 to 50 km., their depths for destructive earthquakes come out comparatively shallow.

Let us now try to imagine how the seismic force acted. Taking first its projection on the zone of activity as a strip along the eastern shore of Tuiyama cove, one end of which is in alignment with the right bank of the lower Maruyama river in a SSW direction and extending to the east of Kinosaki, although it is difficult to form an opinion as to the distance it extended in the other direction. In the absence, then, of any traces of changes in the sea-bed or evidences of tidal waves, (the seiche of Kumihama Bay having no bearing on this subject), the writer hesitates to prolong the principal portion of this area northwards, and would merely place it at a distance some 2 km. from the eastern shore of Tuiyama cove and then extend this a little towards NNE and SSW. This then is the projection on the earth's surface of the block being acted upon by the forces generating the earthquake, although, for reasons previously stated, we take the actual centre of the zone at about 10 km. below the surface. Now suppose that this has been cut by a vertical plane running E-W and that we are looking at one of the cut surfaces from the south. The zone in question will then appear again in front as a narrow strip. This strip is a slant, sloping downwards from east to west, and it is convenient to regard the force as acting along the western side of this strip and in a downward direction from E to W. On this assumption not only the various phenomena connected with the seismic origin, but the distribution of the direction of the preliminary tremors observed at the various stations (Pl. II) will find themselves accordant.

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[1] K. Wadati: Geophysical Magazine, Vol. I, No. 3.

Again, let a line A be drawn through the seismic origin and draw lines B and C, one on each side of A and 200 km. distant from it respectively. Then in the region between A and B the initial phase is directed towards the origin, but in the region A and C, it is directed away from the origin. The explanation of this seems to be that in the case of the initial phase for the region between B and C the seismic waves have been transmitted through the *sial*, whereas for that outside of B and C, the waves have passed through the *sima*. As to the force that acted on the eastern block of the fault, it would appear to be sufficient if we regard it as the result of rebound of the block through release, at the moment of the earthquake, of the long-continued stress which had been acting there, in all probability from the northwest, against the main island of Japan.

4. Causal relationships.

The San-in seismic zone A discussion by the writer on this seismic zone will be found under the title "The Hamada Earthquake of 1872" in the Report of the Committee No. 77, wherein was also described the characteristics of earthquakes that have originated in this zone, together with their subsequent behaviour, and from which it will be seen that the present earthquake originated in the eastern part of this zone, and that as has already been observed, the seismic activity seems to be shifting in a north-easterly direction. It is also to be noted, as is fully dealt with in a subsequent article in this report by Dr. Yamasaki, that with unmistakable signs of the focal zone having undergone conspicuous changes in the past, the occurrence of the present earthquake is not a matter for surprise. In this connection we might add that some of our party were made the targets of uncomplimentary remarks on the assurance of the Kinosaki districts from future destructive earthquakes alleged to have been made by the late Dr. Omori, but it is well to explain that it is highly probable that the assurance was due to some misinterpretations of certain data covering the seismic history of the region.

Premonitory signs. In respect to this earthquake there seems not to have been wanting certain secondary causes deserving notice, one of which was the coincidence of the time of occurrence of the earthquake with the period of the new moon. Of greater significance, however, was the manifestations, prior to the earthquake, of signs pointing to certain agencies at work in bringing about the final catastrophe. The observations of the Toyo-oka station of the Kobe Marine Observatory, although very valuable in other respects, failed to reveal any evidences of foreshocks or earth-tiltings, but it would be illogical to deny even minute tiltings from the negative evidence. The reservoir of the Toyo-oka water-works, which, by the way, was maintained by the private efforts of a public-spirited citizen, was in a locality situated southwards of the Genbudo railway station. We learn that from about the day before the earthquake the water volume appeared to observers as having suddenly diminished.

After the earthquake prospects seemed favourable for a careful re-survey by the Land Survey Department of the levelling route passing through the affected districts, but it failed to materialize, although even if it did, it is a cause for regret that the route extending from the direction of Miyadu, passing through Kumihama and Toyo-oka and then proceeding southwards through mountains, links only distant Tottori without approaching at all the meizoseismal area. In addition to this drawback there is the unfortunate fact that benchmarks at several important points have lost their original identity, not only through the action of the elements but also through the perversity of ignorant people.

We are pleased to be able to say that nearly two years after the above was written, that is on March 7th, 1927, a survey was started as a result of the severe Tango earthquake which followed the Tazima earthquake, and what was most fortunate, the survey took in the latter district as well. The results of this survey have enabled us to deduce changes in the land-level which took place in the regions forming the subject of this paper, and from which it seems that in Toyo-oka and vicinity there was a depression of some 30 cm. in the level districts and about 10 cm. in the hilly sections. From this it is quite natural to conceive of considerable changes having occurred in and around the neighbour-hood of lower Maruyama river, which was only to be expected as a result of the mechanism of earthquake generation referred to in previous paragraph. (See Pl. I.)

Relation with the Outer Seismic Zone. (The two seismic zones lying parallel to the trend of the island arc, one on the western or Japan Sea side, and the other on the eastern, or Pacific Ocean side, are called respectively the Inner and Outer Seismic Zones.) During the periods preceding and following the great Kwanto earthquake of 1923, activities were displayed by the outer seismic zone and continued for some time, so that the severe Tazima earthquake which took place in this period may safely be considered as having had some causal relationship with the great Kwanto visitation. As parallel cases we may take the earthquake which originated at sea off Kusiro and Nemuro (Hokkaido) on the 22nd of March, 1894, with the one that occurred at Sakata (Ugo Province) on the 22nd of October of the same year. In 1896, on the 15th of June, came the great submarine earthquake of the N.E. Japan which was accompanied by that great tidal-wave, whereupon on the 31st of August of the same year, the provinces of Ugo and Rikutyû in northern Japan were visited by a great earthquake. Dr. Suyehiro has called attention to a similar sympathetic relationship in the case of the present earthquake, and indeed it is not impossible to trace connections between the inner and outer seismic zones of Japan. For example, after the great earthquake and tidal-wave had visited the provinces of Hyûga and Osumi in the year 1662, that is fourteen years later, in the year 1676, there was an earthquake in Tuwano in the province of Iwami. Four years after the great earthquake and tidal-wave in the Nankaido, namely in 1711, there was an earthquake at the boundaries of the three provinces of Mimasaka, Inaba and Hôki. On the 23rd of December, 1854, a severe earthquake originated off the Tokaido and the following day another big one originated off the Nankaido with tidal-wave, and within a period of from three to four years after this, four severe shocks struck Tuwano and Hamada in the province of Iwami, throwing down walls and stone fences, with finally the very violent earthquake of Hamada of 1872. Seeing, therefore, that the present violent earthquake occurred one year and eight months after the great Kwanto earthquake of 1923, we cannot very well refuse to acknowledge the relationship here as were found for the foregoing examples.

APPENDIX

Observations of Aftershocks at the Different Stations.

(P: Toyo-oka 11 h 9 m 57 s, Kôbe 11 h 10 m 2 s, Osaka 11 h 10 m 4 s)

No.	Toyo-oka				Kobe			Osaka		
	Date			Inten-sity*	Time		Dur. prel. tr.	Time		Dur. prel. tr.
	May d	h	m		h	m	sec.	h	m	sec.
1	23	11	10.0	VI						
2		11	10.2	,,						
3		11	10.2	,,						
					11	19.9				
					11	21.2				
					11	21.7				
					11	24.6				
4		11	37.3	V	11	37.7	11.4	11	38.7	13
					11	38.7				
5		11	46.5	,,						
6		11	47.6	,,	11	59.8				
7		12	01.3	,,	12	02.7	13.8	12	02.8	14
8		12	07.5	IV	12	08.9	13.3			
9		12	22.9	,,	12	23.3	13.3			
10		12	31.7	,,	12	32.2	12.4			
					12	35.3				
					12	40.7	13.6	12	40.9	12
11		12	55.4	,,						
					13	15.4				
12		13	52.5	,,	13	52.9	13.7	13	53.0	19
13		14	00.2	,,	14	00.9	13.0	14	01.0	15
14		14	02.0	,,	14	03.5				
15		14	47.3	,,	14	47.7	13.4	14	47.3	14
16		15	43.3	,,						
17		16	25.7	,,	16	26.4	13.6	16	26.5	12
					16	30.9				
18		17	08.4	III	17	09.4				
					17	09.5	12.3			

* I=slight, II=rather weak, III=weak,
IV=rather strong, V=strong, VI=violent.

No.	Toyo-oka		Kobe		Osaka	
	Date	Intensity	Time	Dur. prel. tr.	Time	Dur. prel. tr.
	d h m		h m	sec.	h m	sec.
19	23 17 19.3	II	17 20.1			
			17 32.1			
			17 38.2			
			18 05.2			
20	18 27.1	,,	18 28.7	13.3		
			18 39.0	13.3	18 39.0	19
			18 46.9			
21	18 57.0	,,				
22	22 26.2	,,	22 26.4	12.4		
23	22 27.1	,,	22 27.4			
24	24 1 50.0	,,	1 50.4			
			2 16.0			
25	8 10.7	I	6 05.9			
26	9 33.8					
27	9 39.5					
28	9 53.0					
29	9 54.0					
30	9 55.5					
31	9 55.8		9 56.0			
32	9 56.1	I	9 56.4	13.0		
33	10 55.9					
34	11 09.5	I				
35	11 19.4	,,				
36	12 35.4					
37	12 56.7					
38	15 46.8					
39	16 46.9	I	16 47.1			
40	16 50.3	,,	16 50.8			
41	17 56.8					
42	17 59.9					
43	19 51.7	I				
44	19 55.3	III	19 55.6	13.9	19 55.7	14
45	20 00.6					
46	20 01.0					

	d	h	m		h	m	sec.	h	m	sec.
47	24	20	03.9							
48		20	32.4							
49		21	04.1							
50		21	23.4							
51		21	54.3	III	21	54.5	12.2	21	54.5	16
52		22	23.5							
53		22	27.4							
54		23	11.7							
55	25	0	21.8							
56		0	41.2							
57		0	47.2							
58		0	49.3							
59		1	20.5							
60		3	38.2							
61		7	00.7							
62		7	16.8							
63		7	20.4							
64		7	32.5	I	7	32.7				
65		7	51.3							
66		9	26.9							
67		9	33.9							
68		10	07.9	I						
69		10	34.2							
70		11	01.7	II						
71		11	13.7	I						
72		14	57.3	,,						
73		15	52.1							
74		17	04.-							
75		20	34.-	I						
76		21	10.-							
77		21	14.-							
78		22	24.5		22	25.0				
79		22	27.8							
80		23	18.3	II	23	18.6	12.0	23	18.6	19
81		23	19.2							
82		23	41.0	II	23	41.4	14.0	23	41.4	19
83		23	41.2		23	42.6				
84		23	44.2	I	23	44.7				

No.	Toyo-oka				Kobe			Osaka		
	Date			Intensity	Time		Dur. prel. tr.	Time		Dur. prel. tr.
	d	h	m		h	m	sec.	h	m	sec.
85	25	23	46.9							
86		23	55.2							
87	26	0	03.9							
88		1	22.3	IV	1	22.6	13.0	1	22.7	18
89		1	26.2	II						
90		1	28.8							
91		1	31.5	I						
92		1	36.9	,,						
93		1	41.9							
94		1	44.4							
95		1	46.3							
96		1	46.6							
97		1	50.9							
98		2	00·9							
99		2	06.9							
100		2	11.6							
101		2	33.9							
102		2	34.9							
103		2	35.6							
104		2	36.7							
105		2	55.5							
106		2	59.5							
107		3	08.9							
108		3	10.2		3	10.8		3	10.7	14
					3	11.3				
109		3	16.0							
110		3	31.9		3	32.2		3	32.2	19
111		3	39.7							
112		3	52.1							
113		4	06.2							
114		4	11.7							
115		4	24.6							
116		4	43.6							
117		4	47.6							

	d	h	m		h	m	sec.	h	m	sec.
118	26	4	48.1							
119		5	17.7							
120		5	39.2		5	39.2				
121		5	43.5							
122		5	49.3							
123		6	20.5							
124		6	38.9							
125		6	42.3							
126		6	52.8							
127		8	12.6							
128		8	33.5							
129		8	42.4	III	8	42.7		8	42.7	15
130		11	28.7	I						
131		14	09.7							
132		14	25.6							
133		14	48.7	III	14	49.0	13.0			
134		14	54.0							
135		15	57.1	II	15	57.5	14.3	15	57.6	14
136		17	22.3							
137		19	29.0		19	29.3	13.3			
138		19	50.5							
139		20	02.4							
140		20	14.2							
141		20	22.7							
142		20	43.0							
143		21	25.1	II						
144		21	36.1	I	21	36.7				
145		21	47.2	,,	21	47.4	15.2	21	47.5	17
146		21	49.7	,,						
147		22	33.4		22	33.7	13.6			
148		22	41.3							
149		23	09.5							
150		23	09.6	I						
151		23	47.7							
152	27	0	30.8							
153		0	32.4							
154		1	10.6							
155		1	21.0							

No.	Toyo-oka				Kobe			Osaka		
	Date			Intensity	Time		Dur. prel. tr.	Time		Dur. prel. tr.
	d	h	m		h	m	sec.	h	m	sec.
156	27	1	28.5							
157		1	40.6		1	40.8	15.0	1	40.9	15
158		1	43.2							
159		1	44.5							
160		1	44.9		1	44.8	11.4			
161		2	01.5							
162		3	01.7							
163		4	59.1							
164		5	12.1							
165		5	17.2							
166		6	52.6							
167		8	16.8							
168		8	41.5							
169		8	42.2							
170		8	47.4	I						
171		8	47.8							
172		10	11.8							
173		10	13.1							
174		11	35.9							
175		12	05.6							
176		12	50.2							
177		13	33.2							
178		13	41.1	I	14	39.0				
179		16	11.0		16	11.3				
180		16	11.3	III	16	11.6		16	11.7	16
181		16	35.0	,,	16	35.5	12.6			
182		16	52.2							
183		17	54.5							
184		18	08.8							
185		18	33.9	I						
186		22	39.4							
187		23	35.7							
188	28	1	33.6	I	1	38.9	13.0			
189		3	49.1							

	d	h	m		h	m	sec.	h	m	sec.
190	28	4	36.6							
191		7	36.1							
192		9	24.4	I						
193		9	45.7	,,						
194		12	44.6							
195		13	08.7							
196		13	10.3							
197		14	10.9							
198		15	02.6							
199		15	30.0							
200		15	46.1	I	15	46.3	13.4			
201		17	37.0							
202		18	55.6	II						
203		19	08.0	I						
204		21	42.9							
205		21	43.5	I						
206		22	40.3	,,						
207		23	38.0							
208	29	0	16.0	I						
209		2	51.2		2	54.8				
210		4	21.6							
211		4	31.1							
212		4	32.3							
213		5	33.8							
214		7	40.0	IV	7	40.3	13.0	7	40.3	15
215		7	40.9							
216		8	24.0	II	8	24.4				
					10	54.2				
217		11	08.8							
218		12	29.9	I	12	30.3				
219		14	24.4	,,						
220		17	47.8	,,						
221		17	48.0	,,	17	48.0				
222		17	48.1	II	17	48.3		17	4.83	22
223		17	49.2							
224		22	18.3							
225	30	6	47.1	I						
226		11	00.9							

No.	Toyo-oka				Kobe			Osaka		
	Date			Intensity	Time		Dur. prel. tr.	Time		Dur. pral. tr.
	d	h	m		h	m	sec.	h	m	sec.
227	30	14	00.7							
228		17	04.3							
229		18	12.7	I						
230	31	0	43.0							
231		7	42.3							
232		10	34.9	I						
233		14	19.3	II	14	19.9				
234		19	33.5	I						
235		20	47.0	I						
236		22	47.2	,,						
	June									
237	1	2	08.6							
238		4	07.8	I						
239		5	28.4	,,						
240		8	49.8	,,	8	50.8				
241		11	41.7							
242		11	45.1							
243		12	12.7							
244		12	27.5							
245		15	28.8							
246		15	44.0							
247		16	37.0							
248		17	55.1	I						
249		23	16.0							
250	2	6	32.6							
251		7	45.4	I						
252		9	02.2	,,						
253		10	37.1							
254		11	31.4	I						
255		12	31.7	,,						
256		12	42.2							
257		12	58.1	I						
258		22	23.4							
259		23	29.9	II	23	30.4				

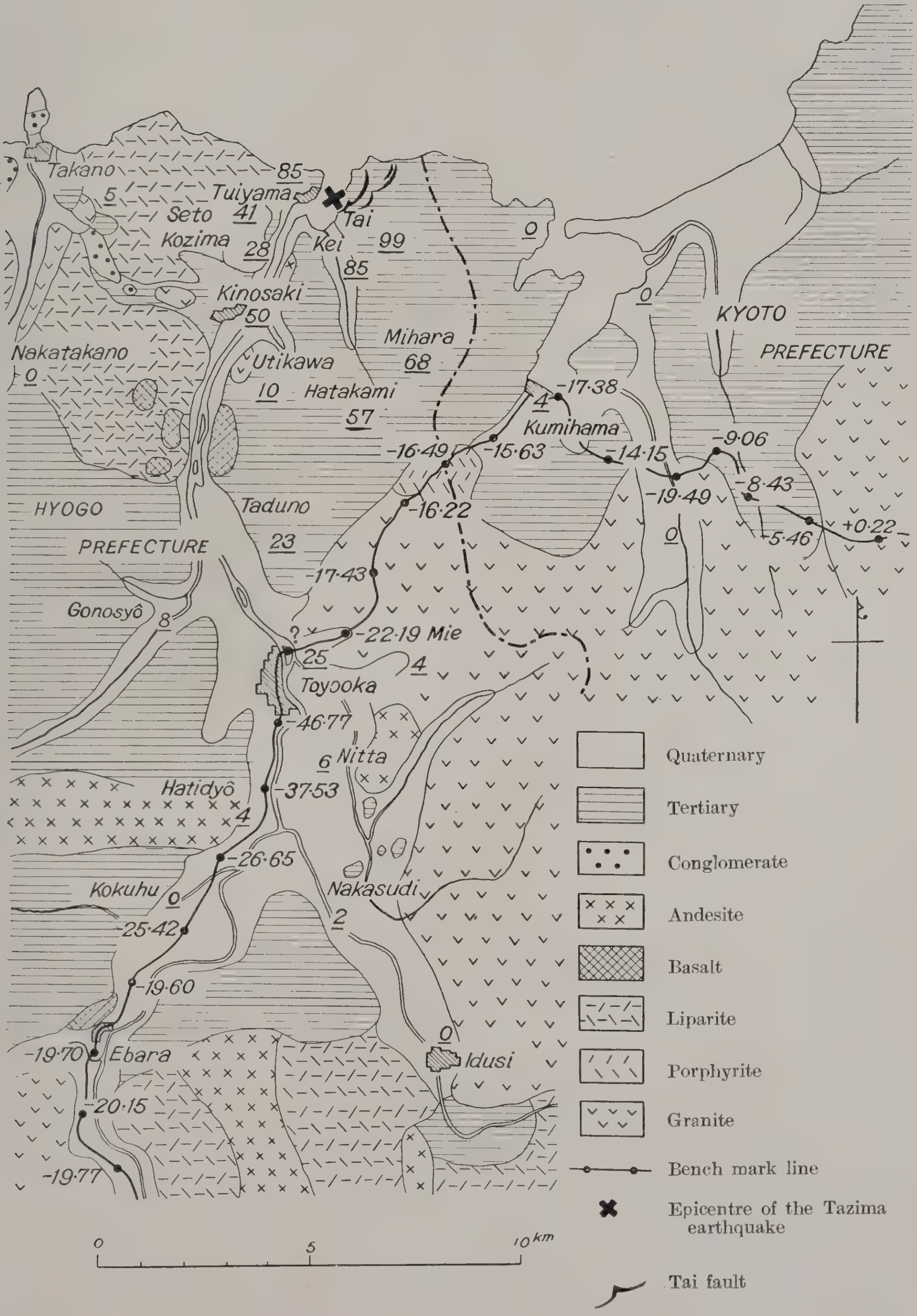
	d	h	m		h	m	sec.	h	m	sec.
260	3	0	25.0							
261		1	31.7							
262		1	32.3							
263		5	43.1							
264		9	57.9							
265		10	59.5							
266		17	41.1	III	17	40.4		17	40.7	36
267		17	41.9	I						
268		17	42.1	,,						
269		23	06.2							
270		23	55.0							
271	4	10	57.1							
272		14	26.0	I	14	26.4				
273		14	58.4	,,						
274		15	48.7	,,						
275		16	38.4							
276		17	09.2	I						
277	5	1	17.0							
278		10	23.2							
279		16	57.9	I						
280	6	2	47.7							
281		12	29.5							
282		12	44.9							
283		12	45.5							
284	7	4	22.9							
285		13	49.9							
286		14	32.8							
287		22	39.0							
288	8	6	51.0							
289		13	27.8							
290		13	36.3	I						
291		15	35.1							
292		17	28.7							
293		17	33.1							
294		20	38.3	I						
295		23	57.0							
296	9	0	22.9							
297		7	05.3							

No.	Toyo-oka				Kobe			Osaka		
	Date			Inten-sity	Time		Dur. prel. tr.	Time		Dur. prel. tr.
	d	h	m		h	m	sec.	h	m	esc.
298	9	7	42.1							
299		7	51.9							
300		15	20.5							
301		17	36.7							
302		22	44.8							
303		22	50.9							
304	10	7	02.2							
305		7	58.6							
306		8	13.7							
307		14	18.4							
308		17	34.4							
309		17	50.8							
310		22	58.6		22	58.8				
311		23	58.7							
312	11	5	17.1							
313		10	00.5	I						
314		10	00.5							
315		10	00.6	I						
316		10	11.0							
317	12	0	11.1							
318		3	48.0							
319		7	46.7							
320		7	46.7							
321		7	53.0							
322		8	14.3							
323		11	44.2							
324		11	44.3							
325		11	44.3							
326		15	57.9							
327		15	57.9							
328	13	6	48.9							
329		15	25.8							
330		7	34.6							
331		7	42.1							

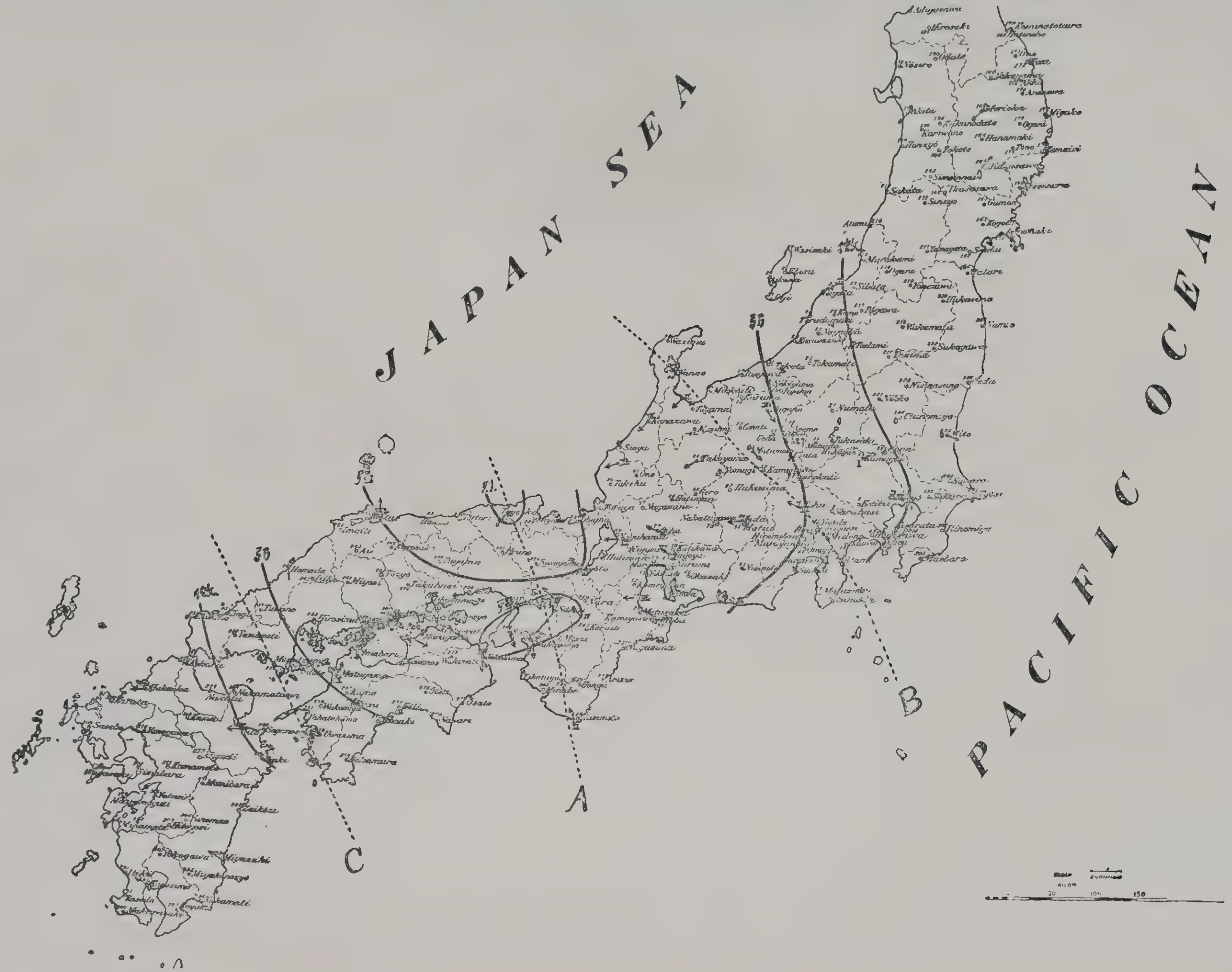
	d	h	m		h	m	sec.	h	m	sec.
332	13	7	50.5							
333		14	49.0							
334		15	12.8							
335		15	13.1							
336	14	0	20.6							
337		9	33.1	I	9	33.4		9	33.5	16
338		9	59.6	II						
339		11	16.9							
340		22	26.1							
341		22	26.2							
342	15	0	01.5							
343		2	10.9							
					10	01.0				
344		11	10.0							
345		11	13.7							
346		11	13.7							
347		15	30.5							
348		18	48.1							
349	16	5	31.9							
350		7	29.9							
351		7	35.7							
352		10	13.5							
353		10	58.2							
354		15	53.1							
355		18	00.3							
356	17	4	32.9							
357		8	37.0							
358		8	43.3							

Pl. I.

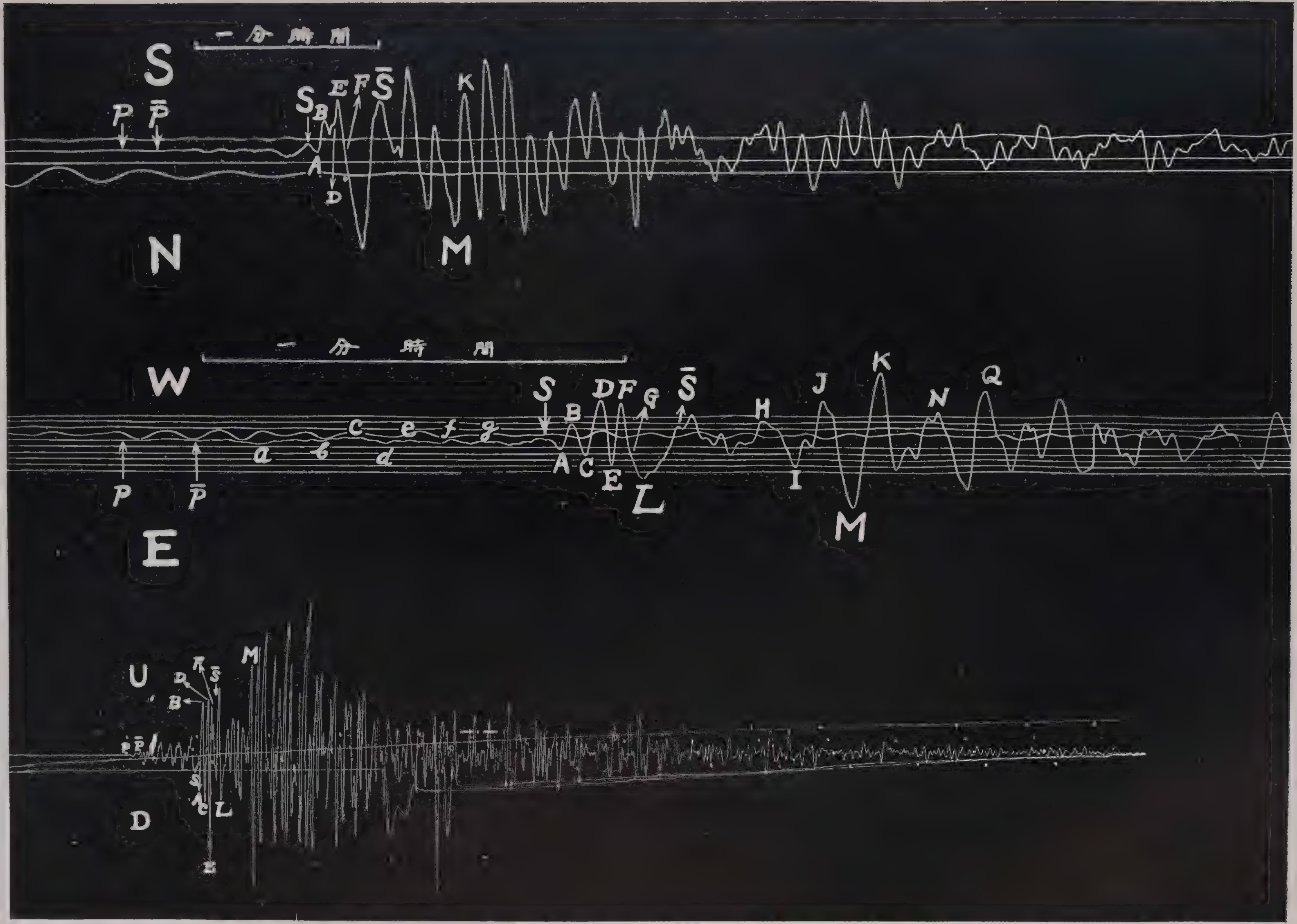
Map showing the seismic area of the Tazima earthquake of 1925. (Numerals underlined denote percentage of houses collapsed. Numerals by the B. M. route denote the height change in cm.)



Isoseismals and directions of the initial phase.



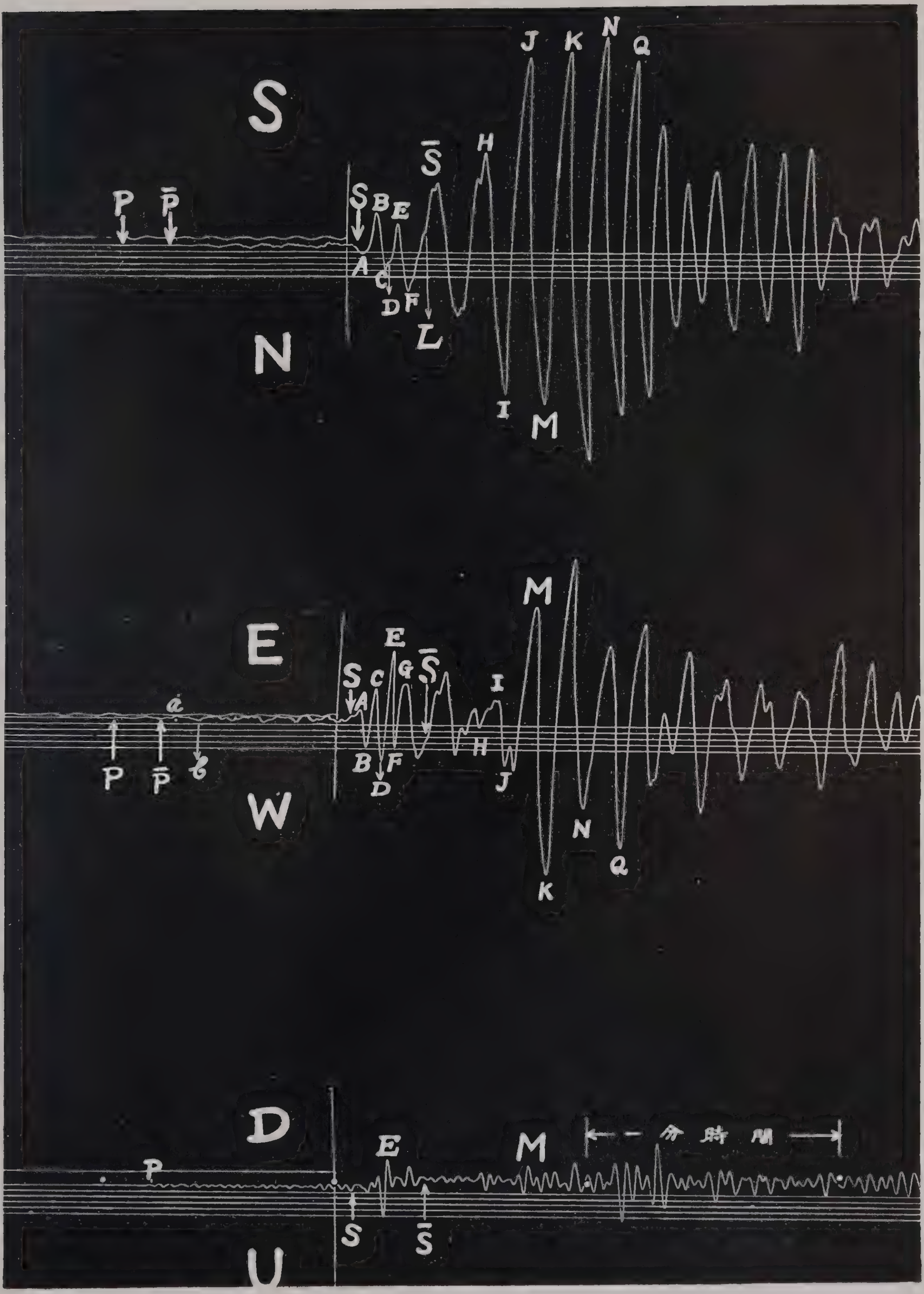
Pl. III.



Tokyo observation of the great Tazima earthquake.

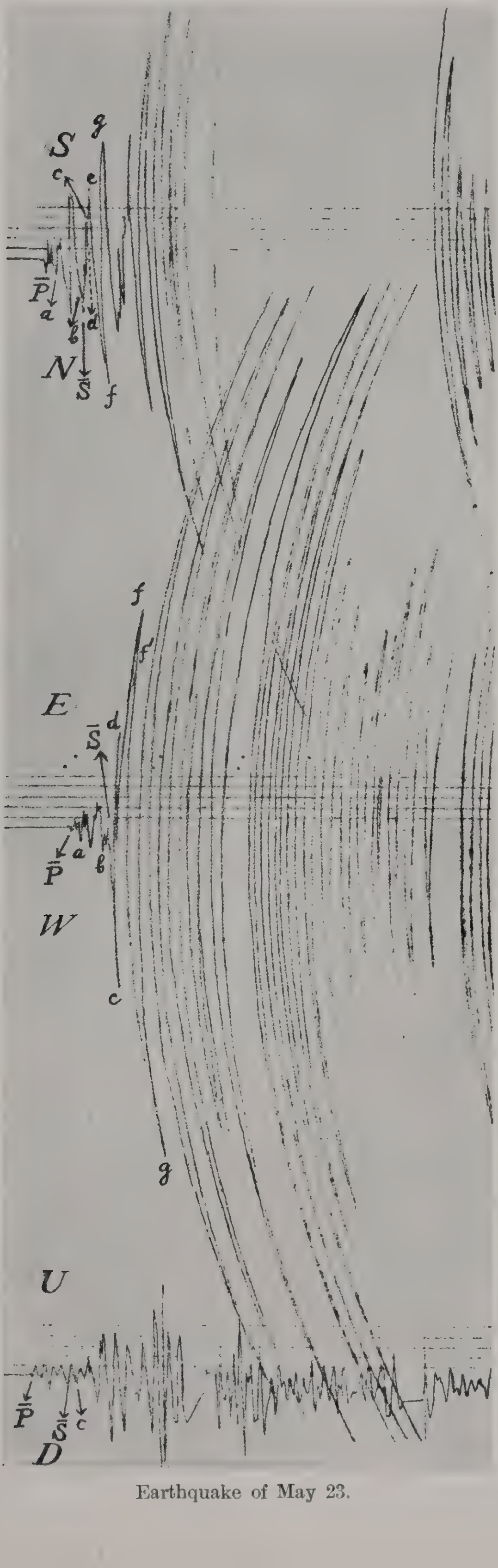
Index magnification: EW=1.5, NS=1.5, Vert.=10.

Tokyo observation of the great Tazima earthquake.
Index magnification = 2, time scale = 4 cm./min.

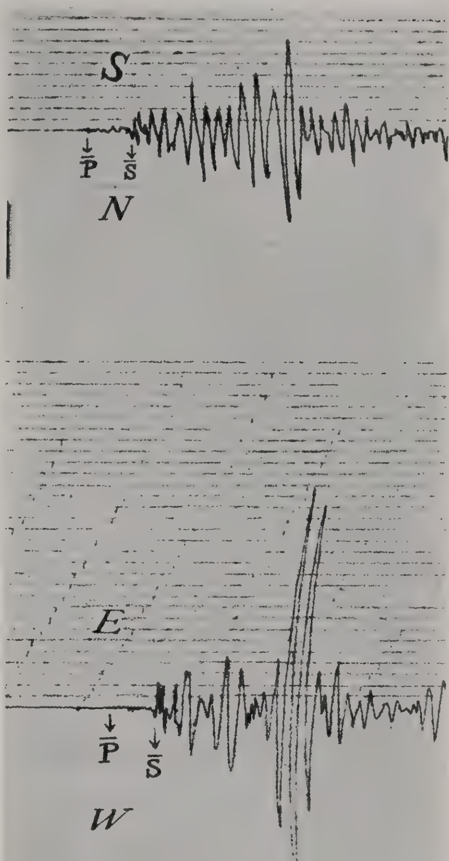


Pl. V.

Osaka observation of the Tazima earthquakes. No index magnification.

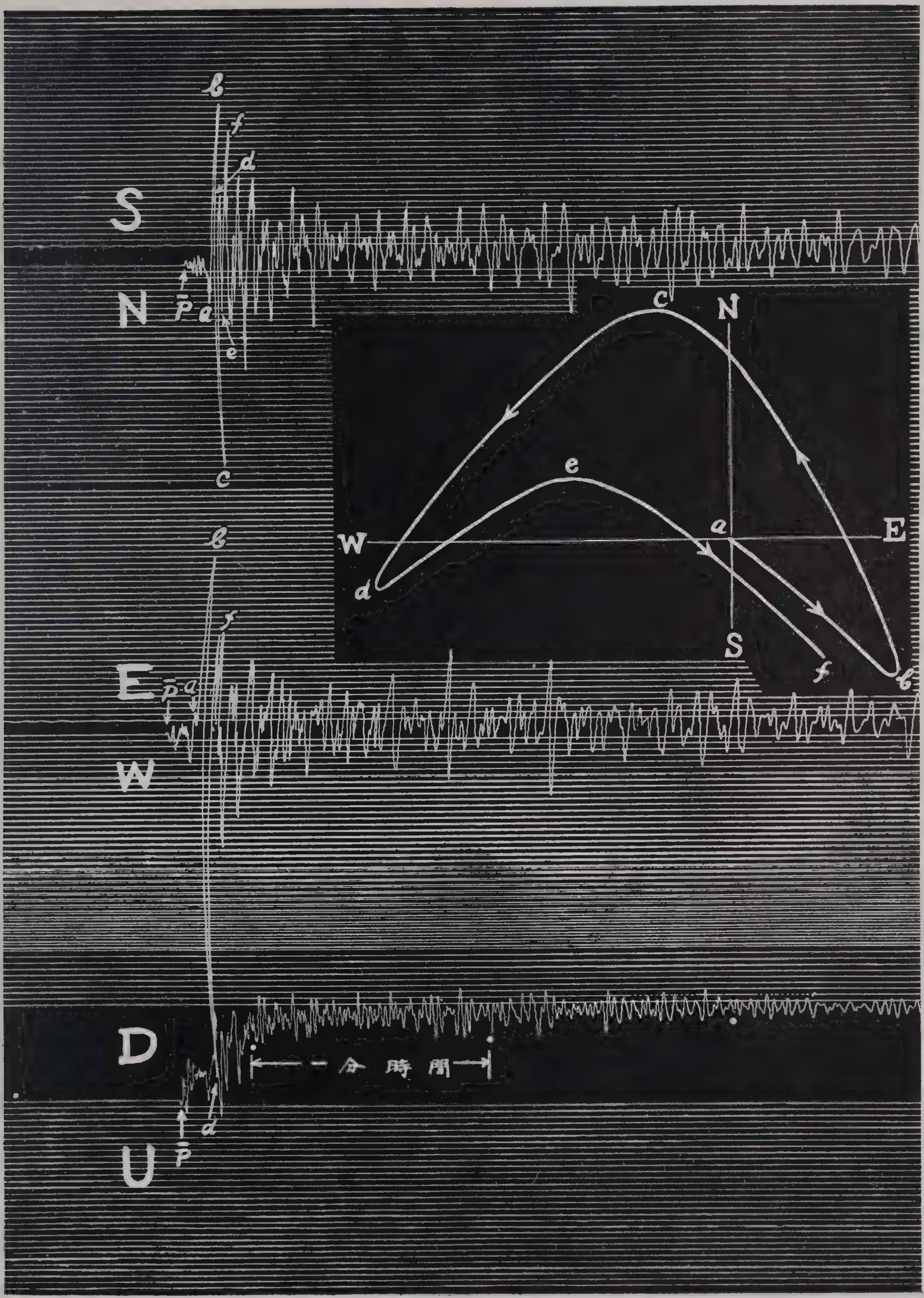


Earthquake of May 23.



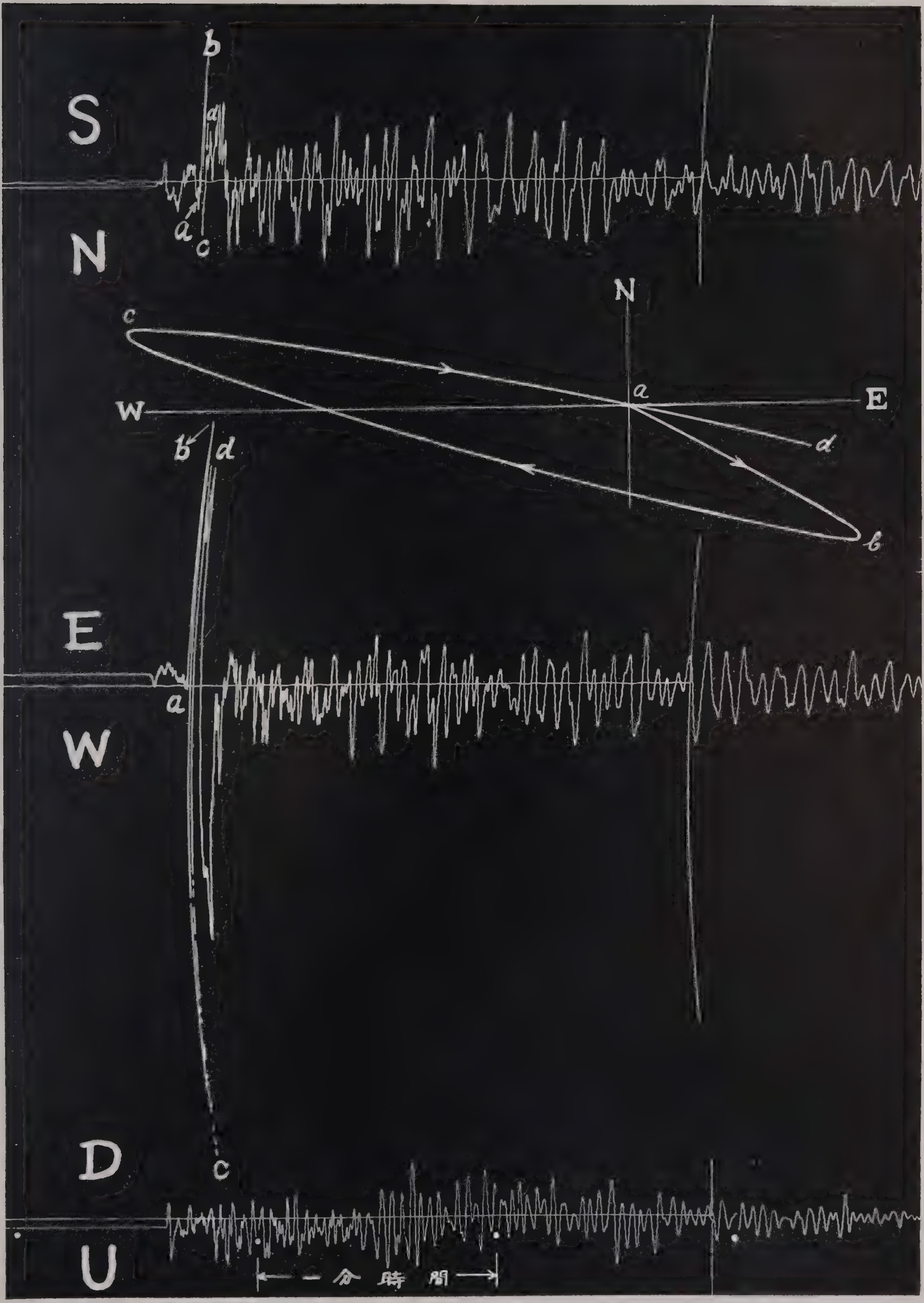
Earthquake of May 26.

Tokyo observation of the Ryugasaki earthquake of Dec. 8, 1921.
Index magnification = 2, time scale = 4.0 cm./min.



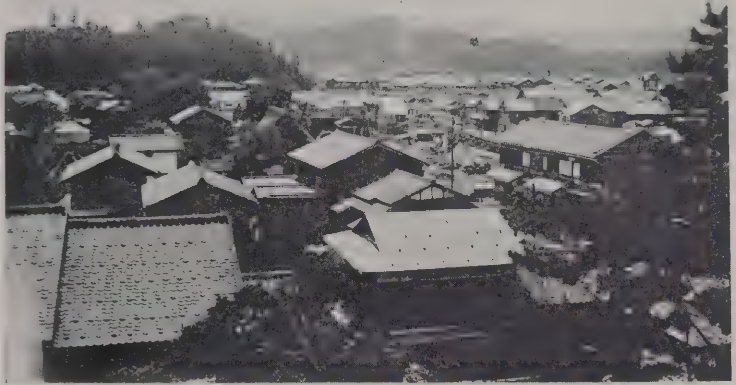
Pl. VII.

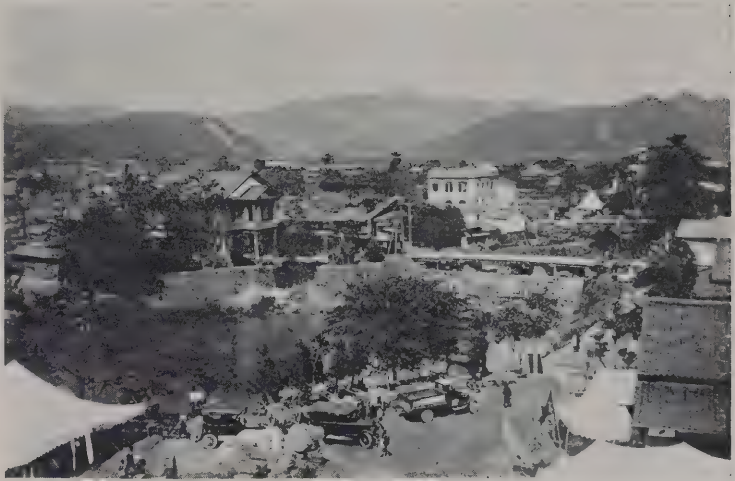
Tokyo observation of the Uraga Channel earthquake of April 26, 1922.
Index magnification = 2, time scale = 4.0 cm./min.

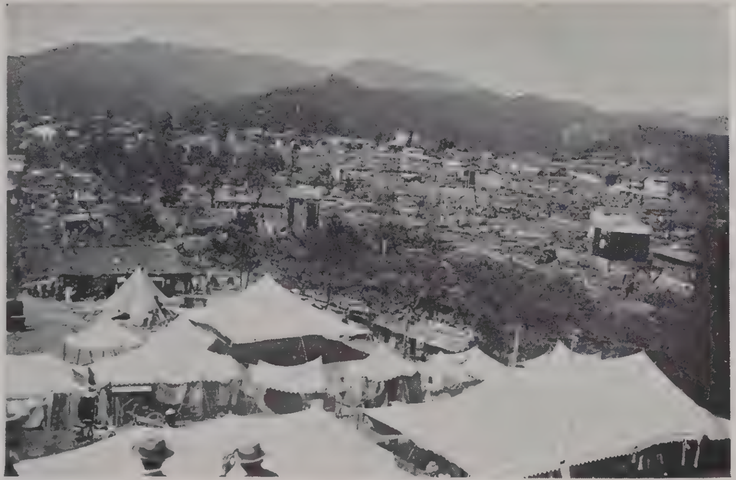


Pl. VIII.

The town of Toyo-oka from the roof of the Toyo-oka primary school.


1


2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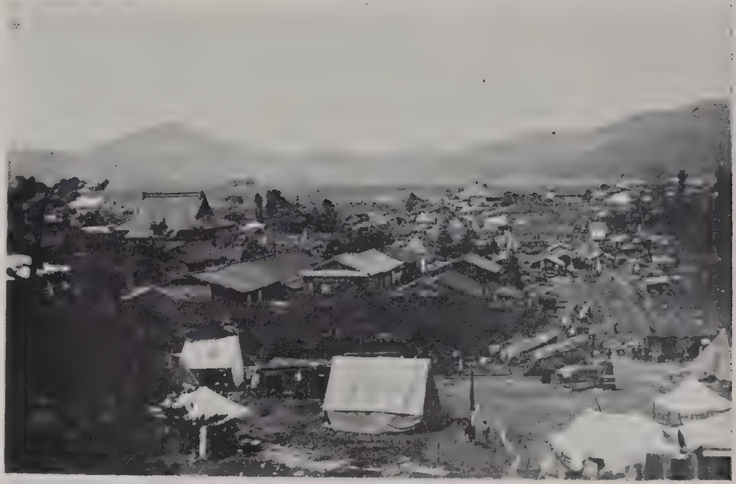
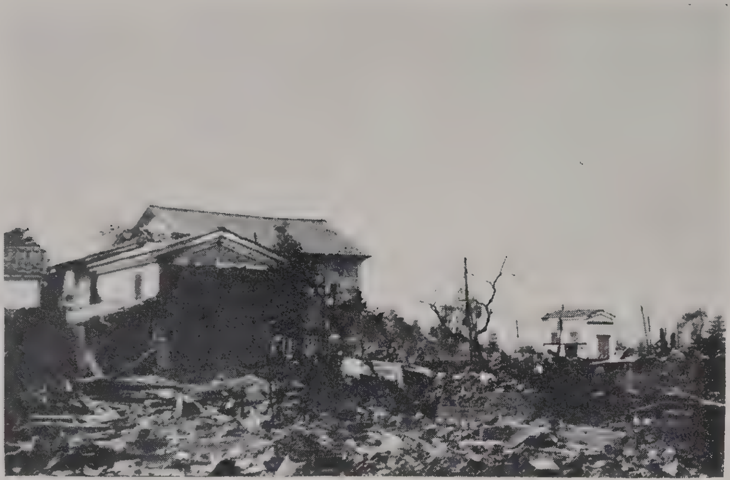
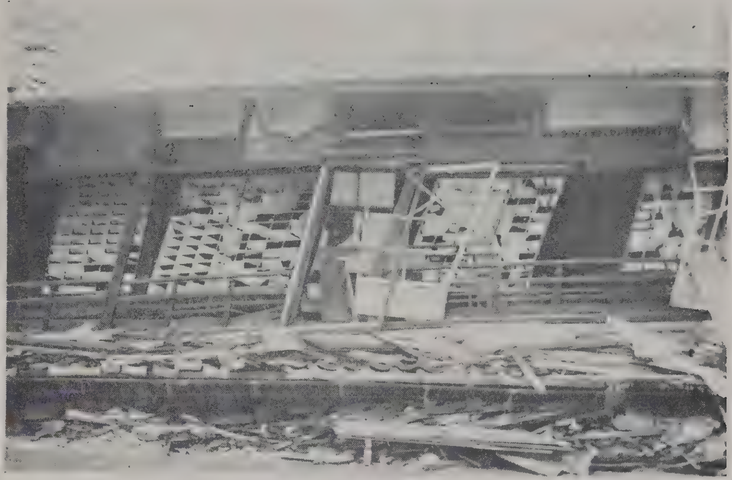
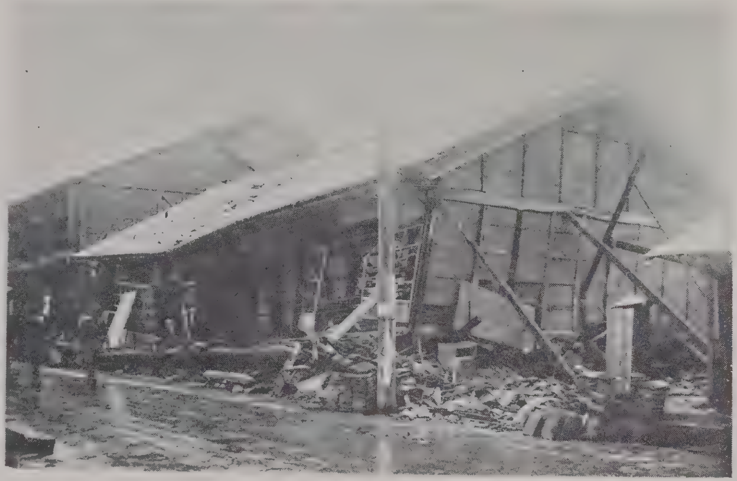

4



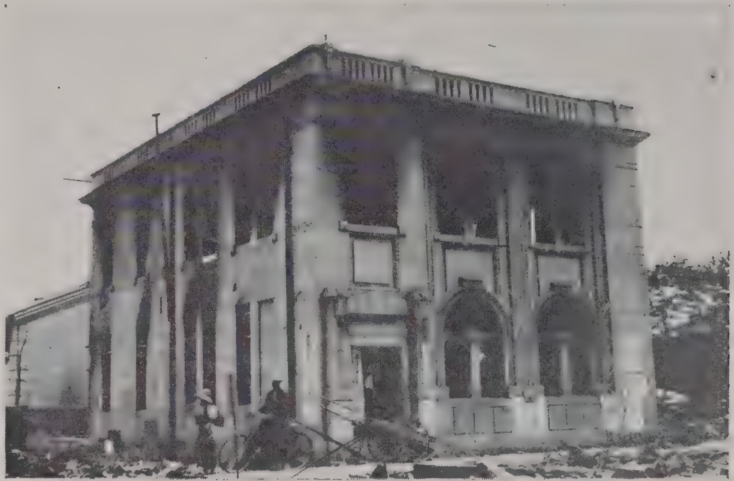
1. Vicinity of the Toyo-oka town office.



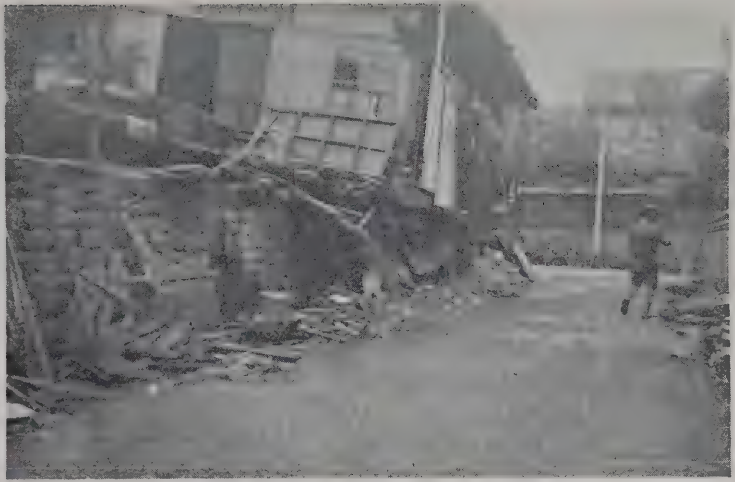
2. Street facing Toyo-oka railway station. Collapse of first story with the second story resting on the ground.



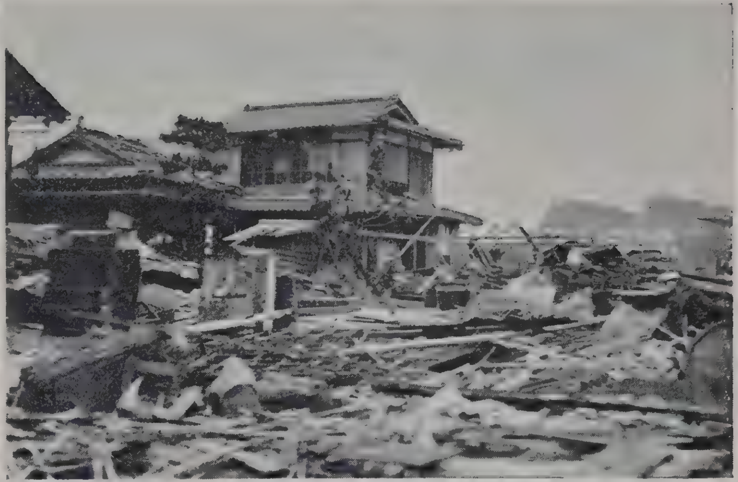
3. Same as No. 2.



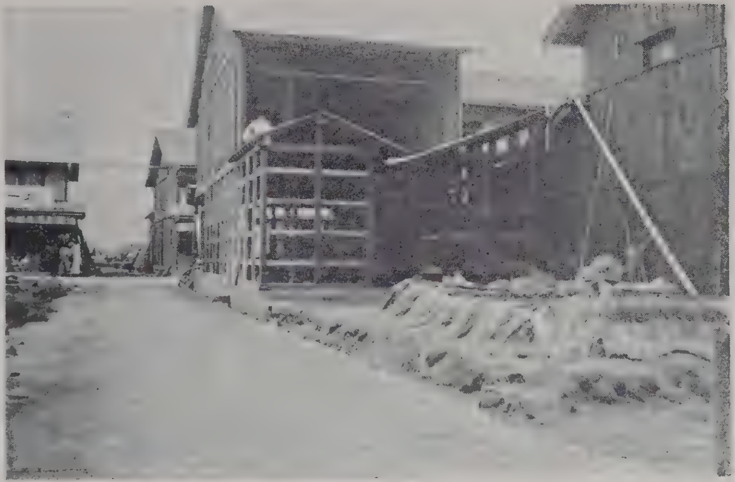
4. Toyo-oka Agricultural Bank building. The interior has been burnt out.



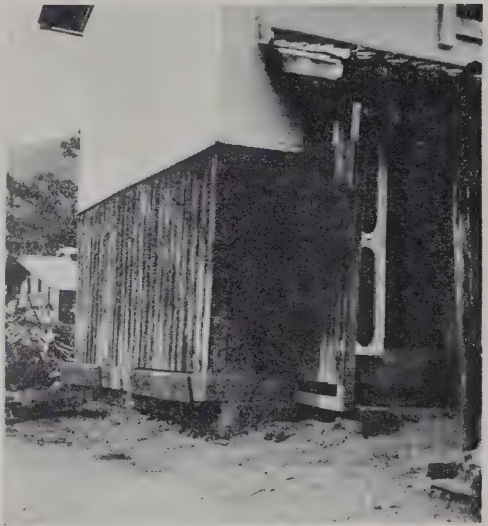
1. A back street in Toyo-oka. Collapse of first story. The second story has taken its place.



2. Toyo-oka. A 2-storied house quite intact because it had many supporting pillars in the walls parallel to the direction of the main earthquake motion.

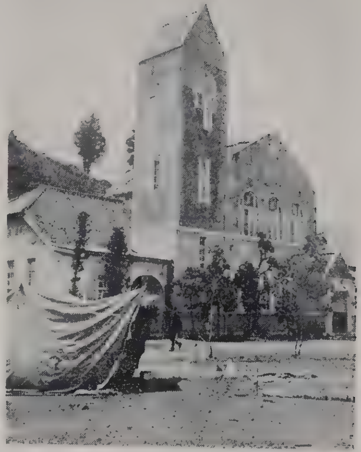


3. House construction typical of Toyo-oka.

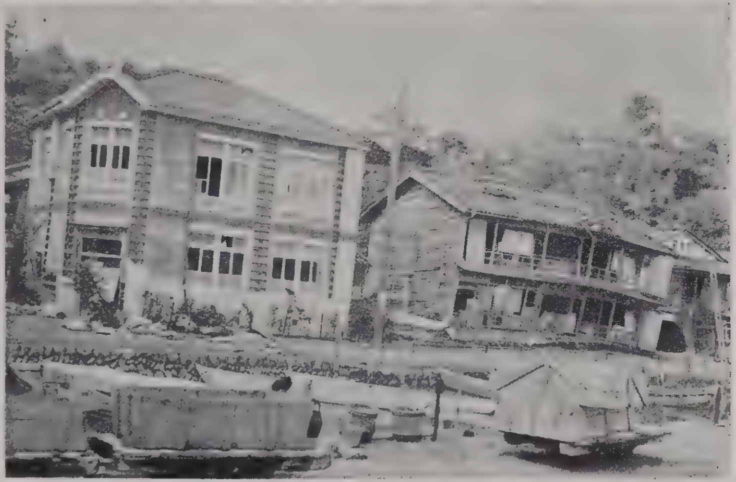


4. Momosima village near Kinosaki town. This mud and plaster warehouse has shifted bodily from its foundation.

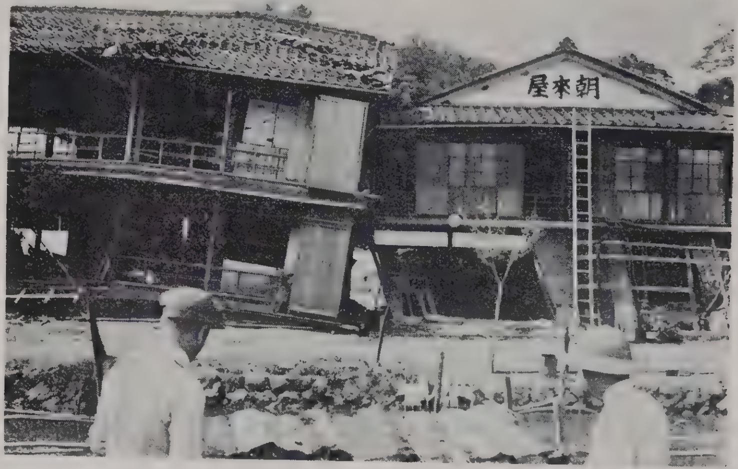
1. Bird's-eye view of Kinosaki after the earthquake.



2. Wooden building of foreign style. Kinosaki. (After Taniguchi.)

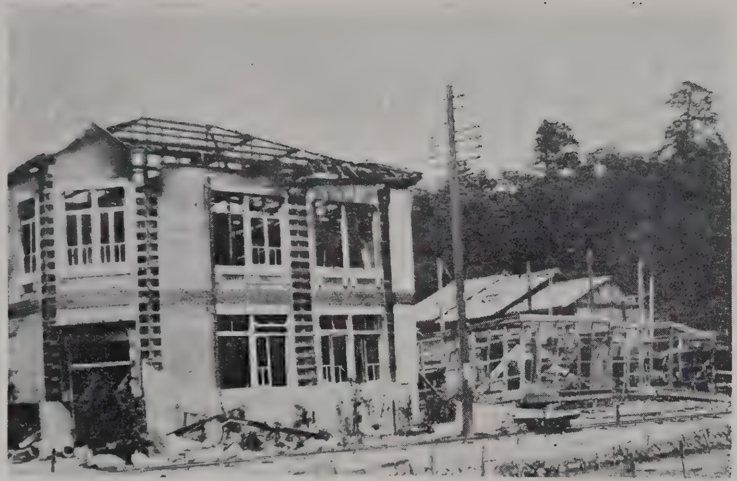


3. Foreign-styled wooden house; collapse of first story of three storied house in the right. (After Taniguchi.)

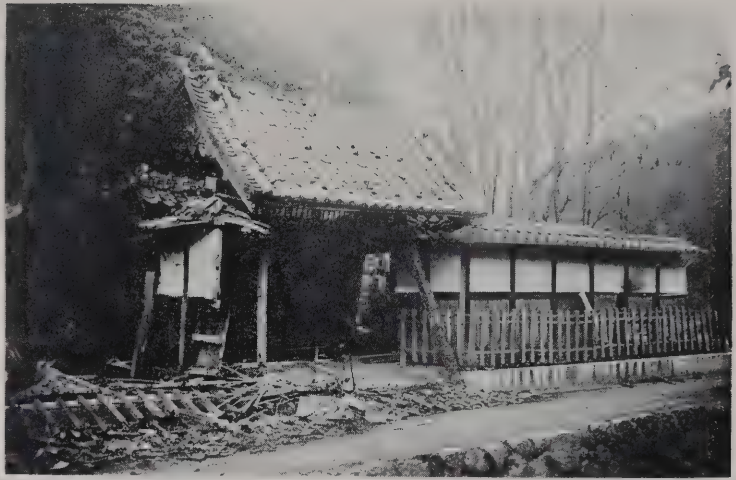


4. Collapse of first story with the second story resting on the ground (left). (After Taniguchi.)

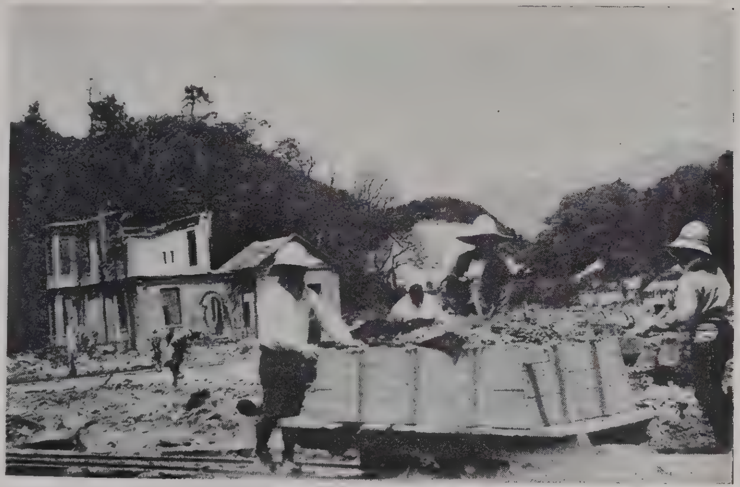
Pl. XII.



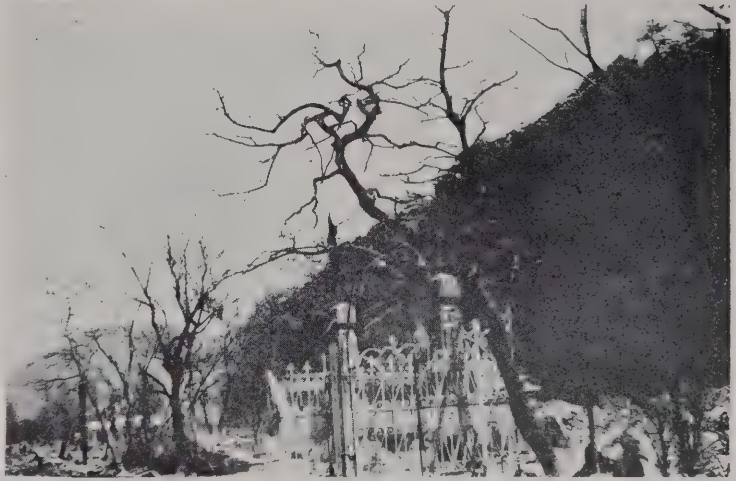
1. A dentist's house, Kinosaki. Burnt on May 29, 1925.



2. A Villa Gunkakuso, Kinosaki.

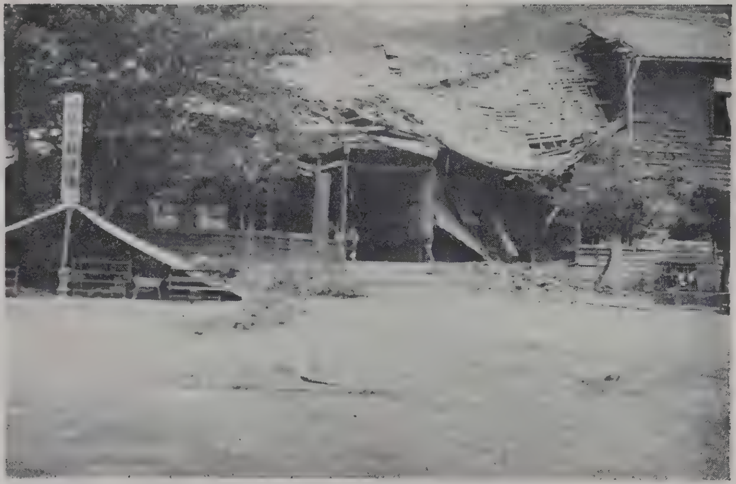


3. Vicinity of Electric-light Co., Kinosaki.

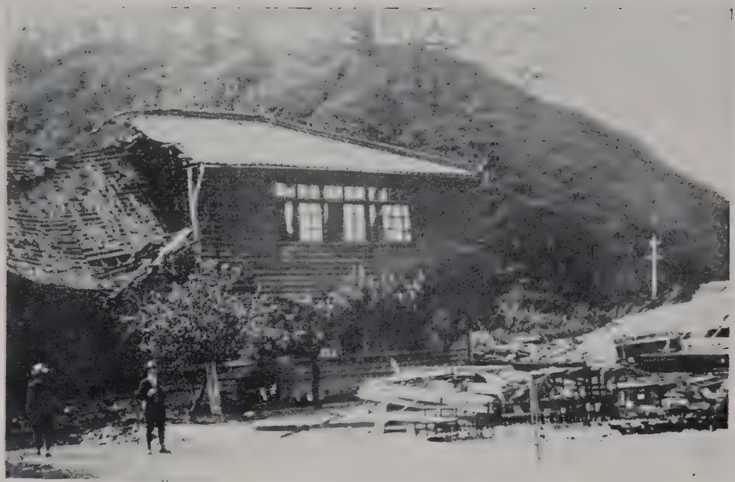


4. A villa Mikiya, Kinosaki.

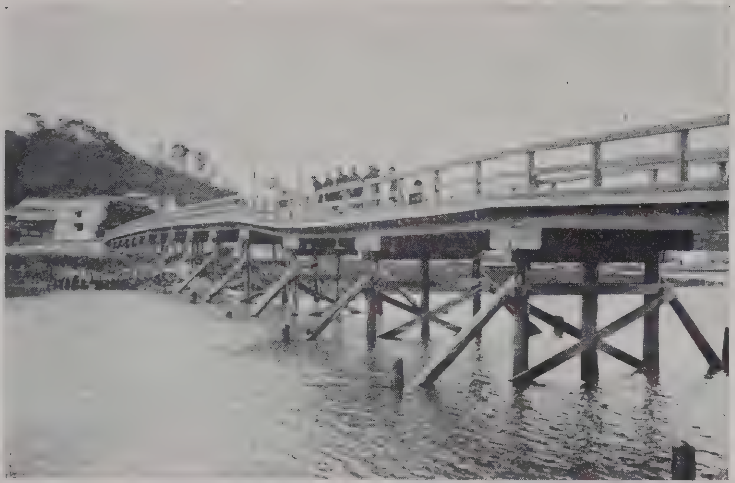
Pl. XIII.



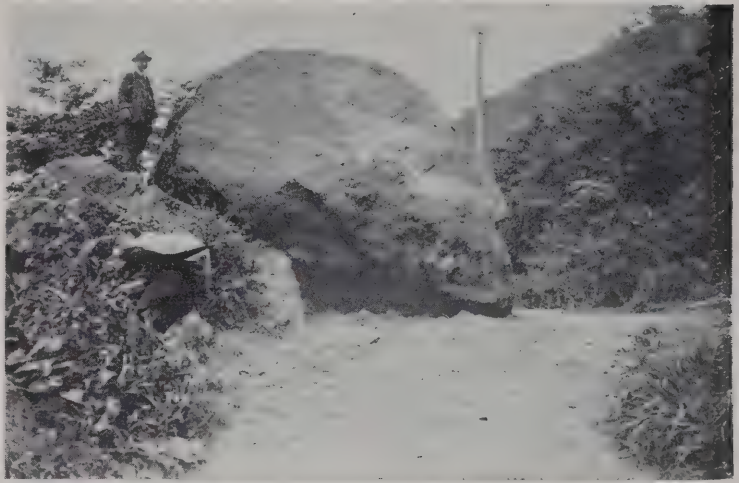
1. Kôsai Primary School.



2. Ditto.

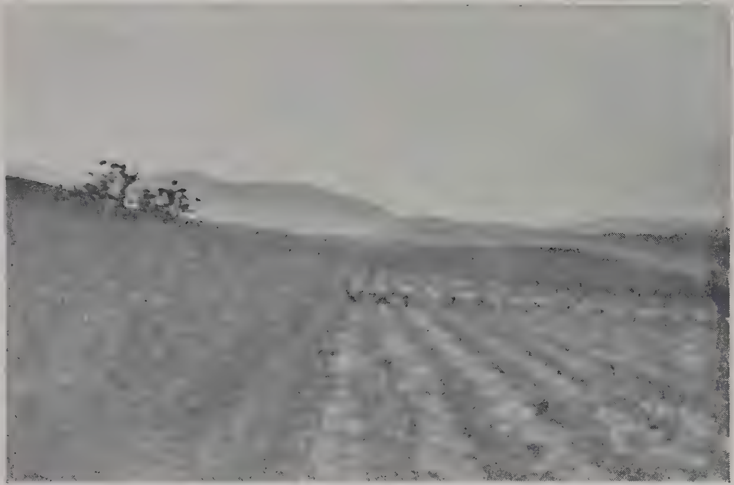


3. Takano bridge. A girder has given way.

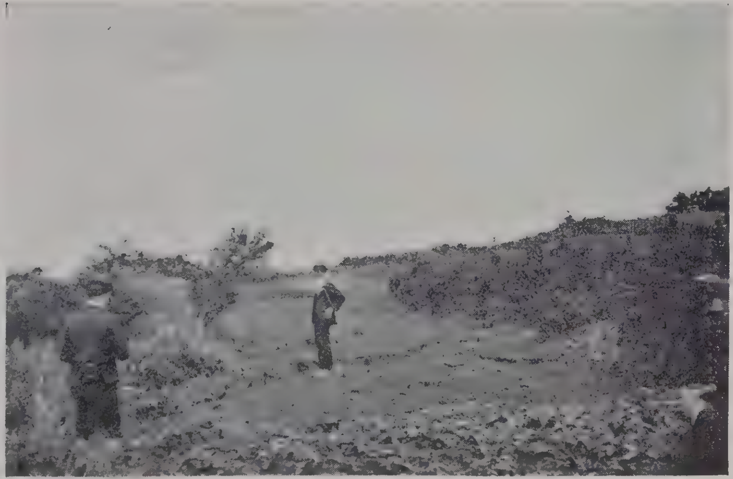


4. Road between Kinosaki and Minato-mura where a big boulder has tumbled down from the hill slope.

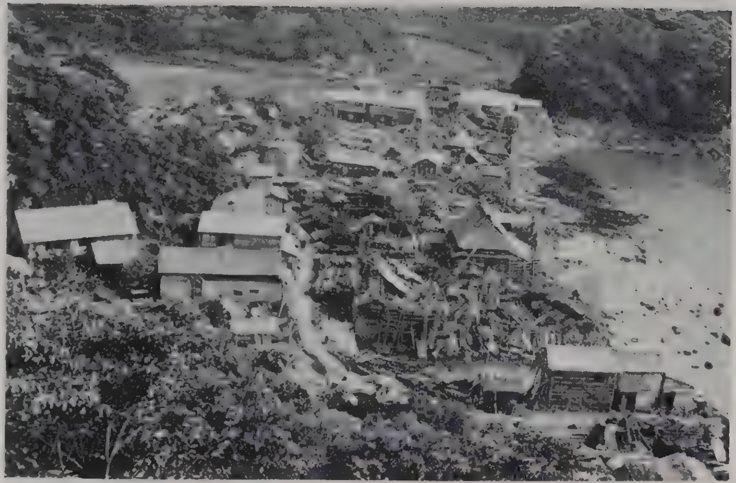
Pl. XIV.


1. A fault traversing a field of young willow shoots.

2. Ditto.

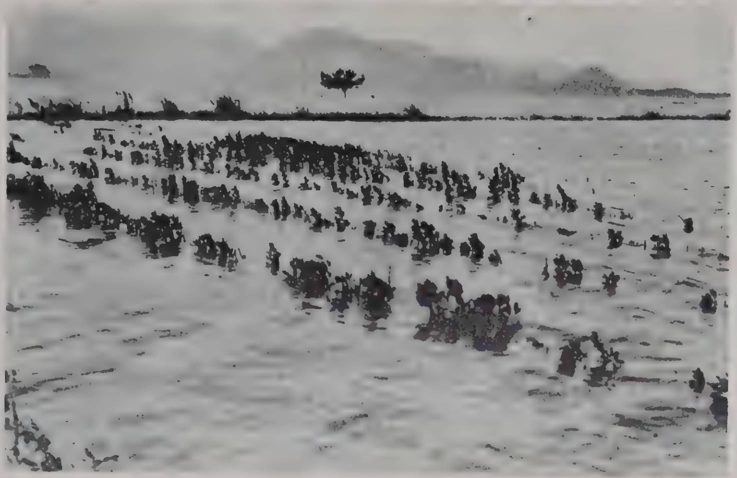

3. A trench.

4. A portion of Tai hamlet and the hill on which the fault originated.
(From Seto hamlet looking east.)

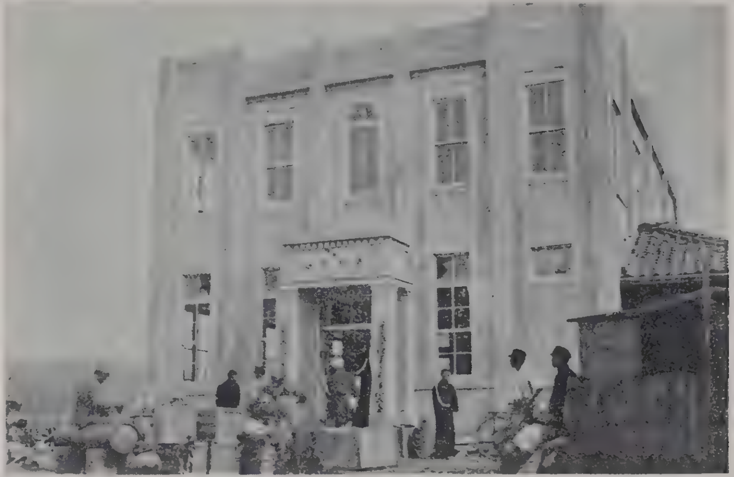


1. Hamlet of Tai. (After Taniguchi.)

2. View of Tai Hill in the epicentral district. (After Taniguchi.)

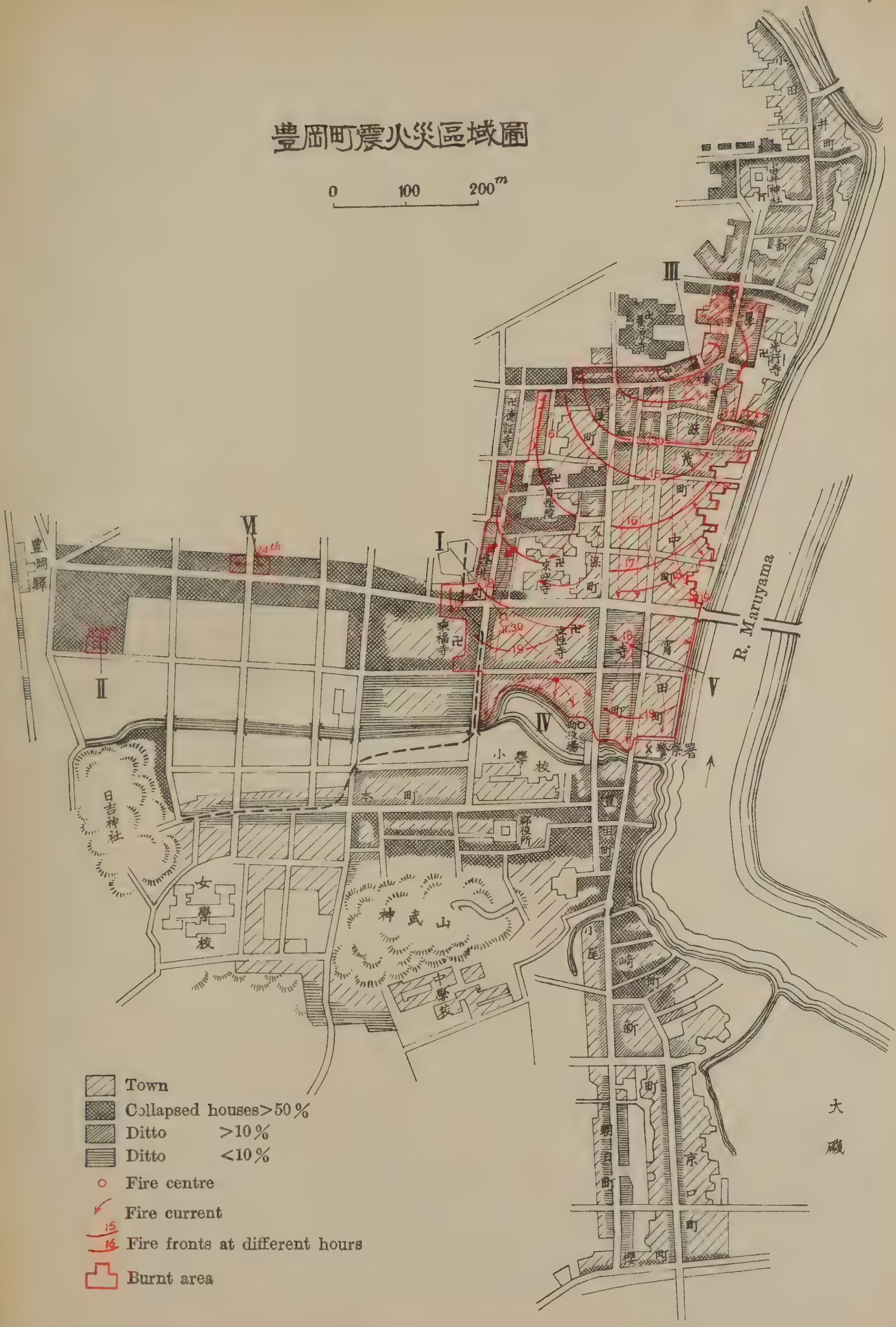


3. Near Kadurano on Kumihama Bay. This mulberry field subsided and is now in 7 feet of water. (After Taniguchi.)



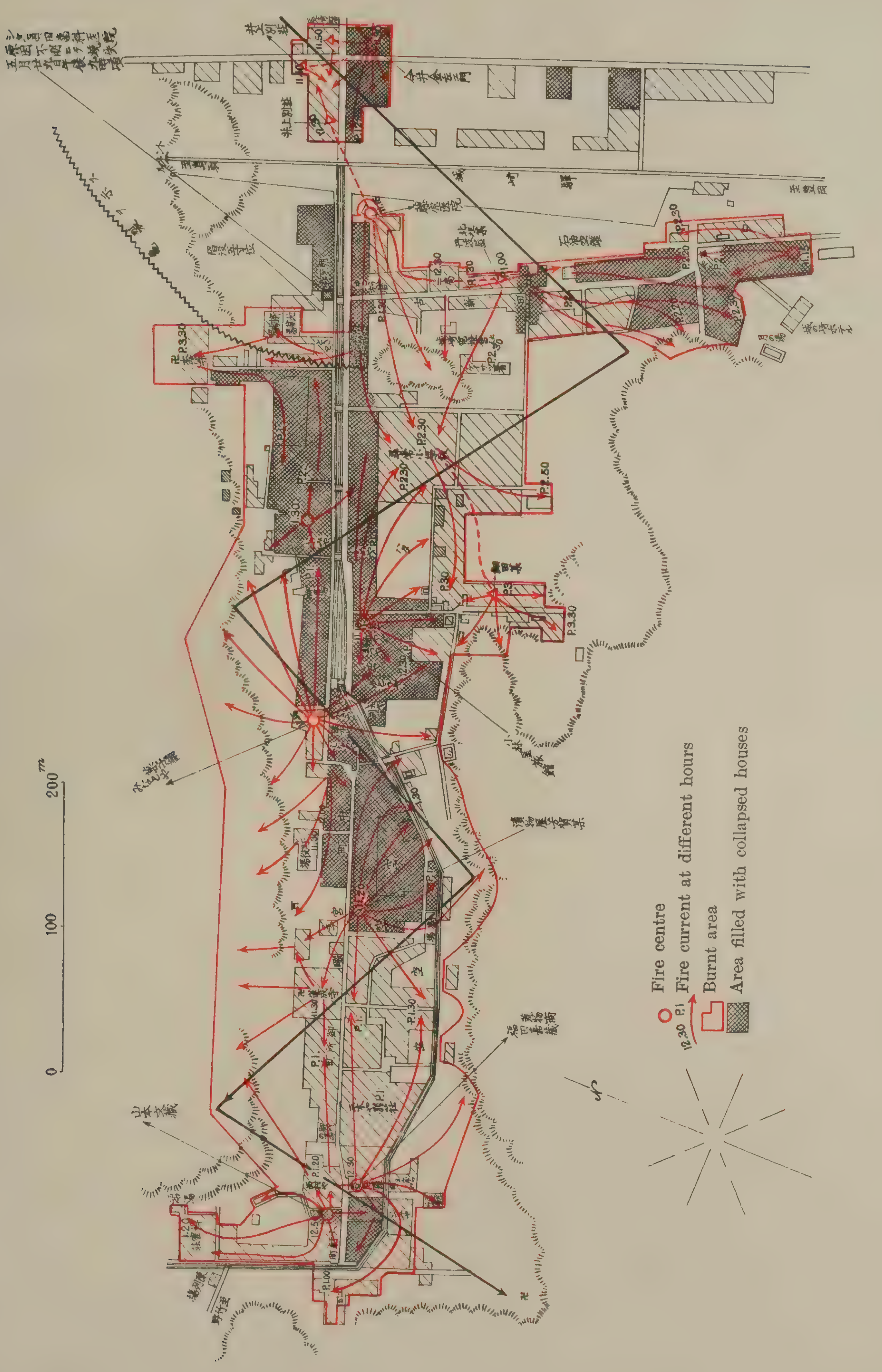
4. A ferro-concrete building in Seto, Minato-mura. Intact. (After Taniguchi.)

Map showing the effects of the earthquake and fire at Toyo-oka. (After Dr. T. Matuzawa, etc.)



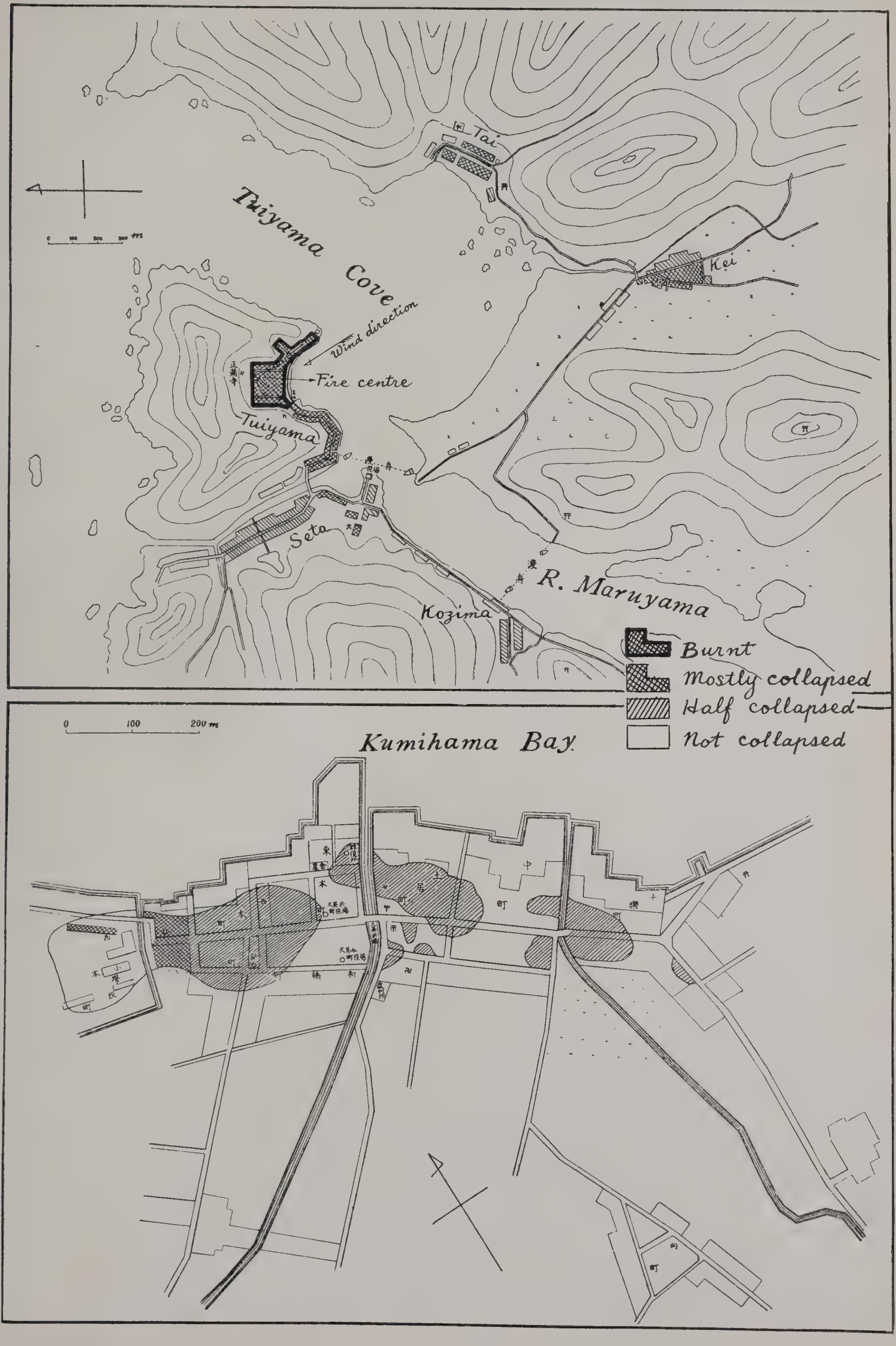
Map showing the effects of the earthquake and fire at Kinosaki. (After Meidi Fire Insurance Co.)

Pl. XVII.


0
100
200m
Fire centre
12.30 P.1 Fire current at different hours
Burnt area
Area filled with collapsed houses

Pl. XVIII.

Map showing the effects of the earthquake and fire in Minato-mura (upper) and Kumihama (lower).



On the Cause of the Tajima Earthquake of 1925

By

N. Yamasaki

(*With Plates I & II.*)

On the 23rd of May, 1925, at 11h. 10m. 49s. the boundary district of the two provinces of Tajima and Tango on the coast of the Sea of Japan was visited by a severe earthquake, the damage being particularly heavy near the mouth of the River Maruyama so that in the town of Tsuiyama, lying where the river discharges into Tsuiyama Cove, practically half the number of houses were shaken down while fire destroyed the rest. In the hamlets of Seto, Tai, Kei, Hanya, Kojima and Momoshima earthquake and fire destroyed nearly everything. At Kinosaki, the celebrated spa of this region, all that could be seen remaining were a few ruined houses, fire having consumed the rest.

At Toyo-oka on the upper course of the river, all houses that were on soft, filled-in ground near the railway station were demolished, but of the remaining houses the loss suffered was due to fire rather than the earthquake, the proportion of the total being 65% of the original number so that fire claimed 1383 houses in all. On the other hand losses suffered by the other hamlets in the vicinity were remarkably small. Towards the neighbouring province of Tango, and also at places lying on Kumihama Bay, the losses were quite heavy, but the region that received the severe damage was an area comprised within an imaginary circle of radius 8 km. described with Tsuiyama Cove as centre. This would leave the town of Toyo-oka as an isolated spot outside of the circle, but the reason for the heavy damage to this town has been given at the beginning of this paragraph.

Detailed reports received from the affected districts being in accord with Dr. Imamura's results of observations at the Seismological Institute of the Imperial University, Tokyo, in pointing to the vicinity of the outlet of the Maruyama River as the origin, the writer decided to make field investigations on the spot, and, accordingly, left Tokyo for the scene of the disaster on the 26th of May in company with Dr. Imamura, Dr. S. Tsuboi and Mr. Suzuki. On the following day we inspected the town of Toyo-oka as well as Kinosaki and environs, while the 28th found us exploring the shores of Tsuiyama Cove and vicinity, where, eventually, on the top of a hill at Tai on the eastern side of the bay, we discovered seismic fault-lines fully exposed to view. The next day, joined by Mr. T. Matuzawa and his party of University students, a thorough examination of this district was made when it was found that there were two parallel fault-lines, and after satisfying ourselves that this was the origin of the present earthquake, we named it the "Tai Fault."

Topography of Tsuiyama Cove and Environ. This region is hilly land with rhyolitic tuff as its foundation, and volcanic rocks such as rhyolite or basalt as overlying ones. Mt. Kurui-dake 560 metres high, to the left of the river, as well as Moriage-yama 426 m. high seen rising towards the west of Seto, together with the other neighbouring peaks, are of rhyolite. The region lying on the right of Maruyama River is chiefly tuff, with outcrops here and there of volcanic rocks, the celebrated basalt cave Genbudō on the river bank being a conspicuous example. Along the river bank the heights of the hills scarcely reach 200 m., but as one proceeds eastwards they suddenly increase to 300 and 400 m. The latter all rise sharply from the sea, forming steep cliffs, on whose sides may be seen layers of tuff traversed by numerous faults, and the way in which the blocks lying between the faults are tilted, exhibit, even within small areas, signs of great crustal changes having taken place after the layers were deposited.

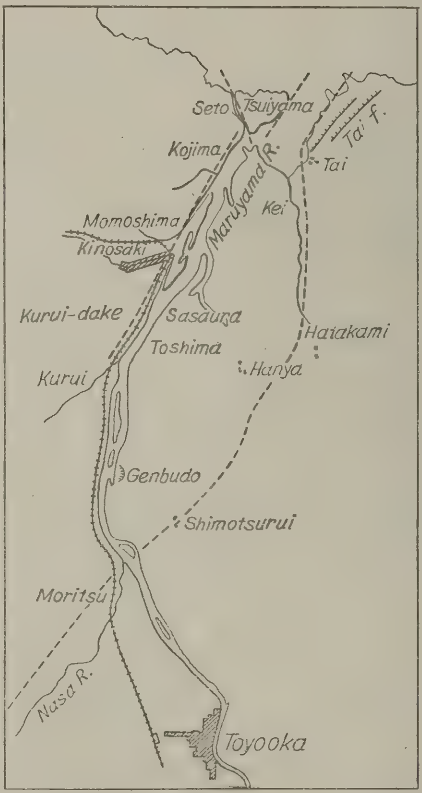


Fig. 1.

On this coast there are two indentations due to tectonic depression the one on the east being Kumihama Cove, and the other on the west Tsuiyama Cove. The former no longer retains its previous shape, its mouth now being almost blocked by a very picturesque sand-bar, while the latter bay is, not only smaller in size, but is more simple in structure, its precipitous scarps being evidences of past depression. In shape, this cove is rectangular and indents itself obliquely in a N.N.E. to S.S.W. direction, its length being about 1.6 km. and the breadth of 0.7 to 1.1 km. The depth at the mouth is 20 m., while at the middle it is quite shallow, being only 5 m. The head of the cove forms the sandy beach of Kei, where the base of the hill which comes quite close to it, checks the waves and shows how recently the sandy beach came into existence. A noticeable feature of Tsuiyama Cove is that owing to its rectangular shape, its two opposite shores, consisting of steep slopes, run in a parallel direction, and that the tops of these slopes are as yet quite level with hardly a small erosion valley developed on them, all of which are eloquent testimony of the quite recent formation of these fault-scarps.

At Tsuiyama Port on the western side of the cove, not only are the hills facing the cove very precipitous, but the western side of the hamlet is also separated from the adjacent hamlet of Seto by a narrow channel, making Tsuiyama a virtual island. This channel is nothing but a fault-line, both the island on one side and the shore opposite being steep slopes. Again on going up the Maruyama River from Tsuiyama, the range of hills on the western side are also very precipitous and one promptly notices that the base of the hills lies almost in a straight line. On viewing this region from the summit of a hill a little to the north of it, its steep slopes are found to have smooth surface, whereas on the tops of the hills just behind them, erosion valleys have developed, the two making an interesting contrast and showing in a vivid manner that the steep sides of the former are fault-scarps.

On examining next the eastern shore of Tsuiyama Cove although, as previously stated, the hill Hachiganaru lying to the north of the hamlet of Tai, shows precipitous fault-scarps for a distance of nearly 1 km. along the bay, it probably joins the steep slopes forming the right bank of the Kei River which flows into the cove, and then continues in a long straight line towards the south. Like the Maruyama River, the valley of the Kei River shows every indication of its being a fault origin.

Dr. Ozawa who visited this locality soon after the writer, on pushing investigations further southwards, found that this fault-line prolonged itself still further, appearing at the hamlet of Shimo-Tsurui on the eastern bank of the Maruyama River and going southwestwards, joined the tectonic valley of the Nasa River. His opinion that the block lying between this fault-line and the Maruyama River subsided within comparatively recent times deserves consideration. (The broken lines shown on Fig. 1. are old fault-lines as distinguished from the new seismic ones just formed in connection with the present earthquake.)

The Tai Fault. The so-called "Tai Fault" consists of two nearly parallel fault-lines on the summit of Hachiganaru hill. Their directions are parallel to the old steep fault-scarps facing the Tsuiyama cove the upper edges of the faults being plainly visible and extending for a distance of nearly 1600 m. The distance between the two lines at its widest part is about 400 m. As shown on the topographical map attached, although the two sides of this hill are very precipitous, upon gaining the summit we find that the top is quite level like a plateau, with indications that it is a remnant of an old peneplain. On the flat surface on the summit of this mountain we found patches of well cultivated ground at heights of about 100 m., where there were being cultivated lilies and willows, the latter being the material for the willow wicker-baskets, the making of which is an important industry of this neighbourhood. This hill-top consists of two parallel ridges, rising from either side of a shallow valley. The fault-lines pass these ridges, one over each ridge, and are visible at the surface. The western fault-line originates from the shore of the bay in the south and continuing upwards, has caused landslides at the top of the steep slopes from whence it passes into Mitano Plateau. On its way northwestwards from here it has caused several clefts and disappearing for a short distance, bends slightly eastwards, and after reaching the plateau it appears again in a most conspicuous manner, that is to say it has caused over ten clefts both large and small, and in one case between two clefts an area some 30 m. wide has sunken in several steps. The width of these clefts ranged all the way from 20 to 30 cm., and the ground lying between the clefts gradually changed in their relative vertical displacements, in amount as well as in sense, so that in going along the fault line we found the subsidence to be on one side of the line at one time, and then on the other side at another, in veritable see-saw fashion. Although the horizonatl movements in one case exceeded 6 cm., its effects were clearly discernible in the disordered rows of the young seedlings in the willow field. As to the cleft of which there were several, the main one caused subsidence on its left hand side, the subsidence reaching its maximum at Noboritate, from whence the fault line clearly extended into the tuff beds composing this locality, eventually losing itself on the top of the hill towards the west of Kanji.

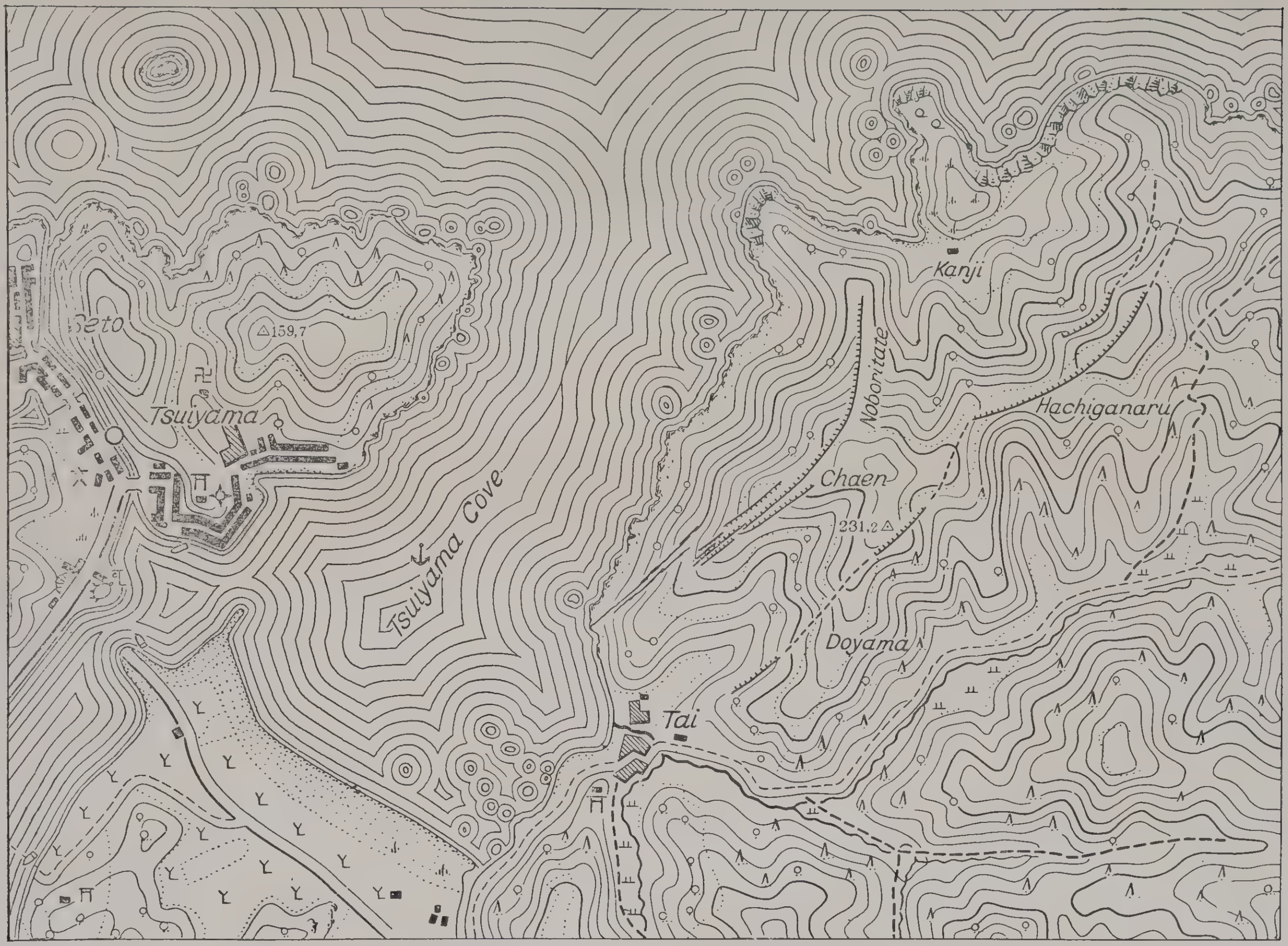
As regards the eastern fault-line, it first shows itself on the southern end of the western scarp of Dōyama Hill, which is behind the hamlet of Tai, and skirting the vicinity of the triangulation mark, goes on to Sasayama and then reaches Hachiganaru, showing itself conspicuously all the way. Although this line does not show many clefts or the trench like conditions of the western fault-line, the subsidences throughout the line follow closely the main characteristics of the other fault-line. We might add that a branch of the main fault-line in passing through a lily field at Hachiganaru has left there an excellent example of horizontal displacement. To the north of Hachiganaru, the fault appears in two separate lines, the westerly one passing through a mulberry field, where the vertical dislocation varies from 60 to 80 cm., and in some places reaching as much as one metre, thus showing the greatest change in the whole line.

Thus the present Tai fault showed itself in two planes almost parallel to the old fault-scarp that faces Tsuiyama Cove and following the very same manner in which the old block subsided on the occasion of the formation of the cove itself, the intervening block subsided towards the west. Undoubtedly this region was the seat of great crustal movements in the past, of which the present one is only a recrudescence.

In addition to the foregoing, clefts were met with on the base of the hills near Tai, while in the hamlet of Momoshima to the north of Kinosaki, in the bases of the hills there were clefts accompanied by small undulations of the ground, but these were caused as a result of the difference between the vibrational periods of the soft soil on one side and that of the adjoining hard ground on the other due to the earthquake motion. To the north of Momoshima this caused wavy undulations in the surface of the dried paddy-fields. Between Kinosaki and Tsuiyama, there were many clefts cutting in the road and fields, while there have been observed here and there sand-cones ejecting water and sand, just as one usually sees in the case of destructive earthquakes.

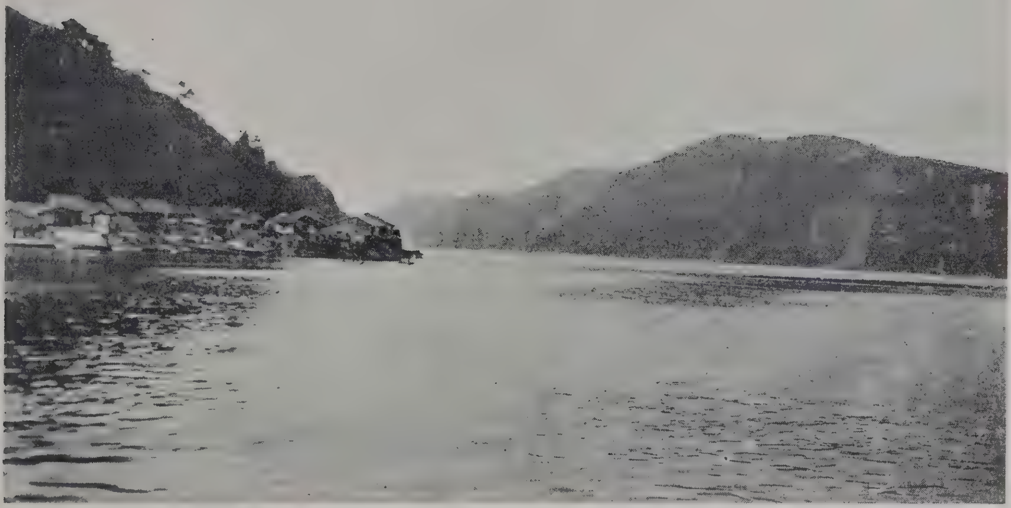
After the writer returned to Tokyo, newspapers reported the discovery of a big fault at Kongaku Valley near Seto, but Dr. Ozawa's examination proved it to be merely a huge landslide.

Pl. I.



The Tai fault 1 : 18.750 (Yamasaki).

Pl. II.



Tsuiyama Cove with Hachiganaru Hill in the background, with steep fault scarps facing the cove. The lighter shaded part is the landslide caused by the present earthquake.

The willow field on the summit of Hachiganaru Hill. The fault is seen in the foreground.

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TOKYO. October, 1928.

TESTS FOR CORROSION MADE WITH STEEL MATERIALS SUBJECTED TO VARIOUS CONDITIONS FOR PROTRACTED PERIODS

By

Y. UCHIDA, *Kogakuhakushi,*
Professor of Architecture,
Tokyo Imperial University,

and

M. HAMADA, *Kogakushi,*
Assistant Professor of Architecture,
Tokyo Imperial University.

(*With Plates* I—IX)

ABSTRACT.

This paper, as the title indicates, presents the results of tests that were made for corrosion by means of steel materials subjected to various conditions for long periods of time. The ages of the test-pieces ranged from 15 to 20 years, and the treatment, as well as the conditions to which the steel were subjected, also varied widely in range. The corrosion of steel placed in concrete, which is particularly important, was tested with concrete of various mixtures as well as with protecting concrete of different thicknesses.

CONTENTS.

Page
1. Introduction 116
2. Results of Experiment Series I 117
3. Results of Experiment Series II 124
4. Concluding Remarks 126

1. INTRODUCTION.

This report covers the results of two series of experiments made with respect to the corrosion of steel materials, the object being to compare the state and extent of corrosion under various conditions and during protracted periods of time.

The earliest experiments were taken in hand by Professor Sano in October, 1907, on behalf of the Earthquake Investigation Committee, and the changes undergone by the materials during stated intervals carefully noted. The changes that were observed at the end of 2 years and 7 months, together with those at the end of 5 years, have already been made public as reports Nos. 1 and 2 in the Reports of the Imperial Earthquake Investigation Committee, Nos. 74 and 76 (in Japanese), but owing to the circumstance that some of the test materials had been allowed to remain under the same test conditions until December, 1927, that is for a period of 20 years, they were examined again after the lapse of this long period, the results of which form a part of the subject of this paper.

The second experiment, which followed that of Professor Sano above mentioned, was begun in October, 1912, by the senior writer of us, and covered a period of 15 years. It supplements the preceding experiment by Prof. Sano, and the present note being the results of these two series of experiments thus carried out.

Owing to the very long periods of time involved, we believe that the results obtained are of value in connection with the important problem of steel corrosion. Our only regret is that owing to loss of some of the materials which were under test, they were not available for the second experiment, so that our investigation is not so complete as we could have wished.

For the benefit of those to whom our previous reports as above mentioned are inaccesible, we have included in the present paper a resume of their main results in order to avoid any discontinuity in the discussion as a whole.

2. RESULTS OF EXPERIMENT SERIES I.

These tests were made for the purpose of studying corrosion with respect to the following subjects:

A. Changes in the steel materials according to manner of use.
B. Changes in the steel materials of different thicknesses.
C. Value of preservative coatings on steel materials exposed to the atmosphere.
D. Changes in the steel material embedded in concrete as well as in its preservative coatings.
E. Changes in the steel materials embedded in concrete of various compositions.
F. Changes in the steel materials embedded in concrete of different thicknesses.

Excepting for B, the material tested upon was a $\frac{3}{4}''$ round mild steel bar made into tension test-pieces of 15″ length, and turned down at the middle for a length of 9″ to a diameter of $\frac{1}{2}''$: its mean tensile strength being 4200 kg/cm^2 and elongation 22.2%.

A. Changes in the steel materials according to manner of use. The $\frac{1}{2}''$ round test-pieces, polished, but without application of any paint or preservative coating, were placed in the following situations:—

(a) Indoors.
(b) Outdoors.
(c) Underground.
(d) Under water in a pond.
(e) Inside a brick block.
(f) Inside a block of concrete.

and the effects of corrosion noted. It is however to be regretted that the test-pieces for (a), (c) and (d) were lost, so that they were not available for the last observation made after 20 years. The results of all tests, with these exceptions, have been tabulated to enable ready comparison in Table I annexed.

Table I. Effects of Rust on Steel Materials according to Manner of Use.

Situation of test-piece	Details	Results		
		1st exam' after lapse of 2 years & 7 months	2nd exam' after lapse of 5 years	3rd exam' made after lapse of 20 years, or 15 years after the 2nd exam'
(a) Indoors	Air exposed in the model room of dep't of Architecture.	Only about 10% of the surface rusted.	About 50% of the surface rusted.	Test-piece lost; no exam'.
(b) Outdoors	Air exposed in a dry area by the old main Engineering building.	Scaly rust peeling off like bark of old pine tree. Complete removal of rust caused loss of 9% of original weight.	Appearance much as in 1st exam', but rust greatly advanced. Removal caused 27% loss of weight.	Externally as in preceding column, but extent of rust remarkably advanced. Removal caused 70% loss of weight.
(c) Underground	In red earth outside of above building.	Covered with a mixture of soil and rust, to remove which caused loss in weight of 1.7%.	Rust increased, to remove which caused loss of 3% of weight.	Test-piece lost; no exam'.
(d) Under water	In a pond in the university compound.	Only a thin rust film formed on the surface	Surface pitted here and there with rust. Removal caused 2.9% loss of weight.	do.
(e) Inside a brick block	Test-piece placed in the center of a brick block of one brick square (9″ square), and built up 2 ft high. Exposed in the open.	About 2/3rds of entire surface was covered with irregular patches of rust.	Nearly 4/5ths of entire surface covered with patches of red and black rust.	Entire surface covered with red and black rust, to remove which caused loss in weight of 2%.
(f) In a block of concrete	Embedded in a block of concrete of mixture 1:3:6 and 6″ × 6″ × 24″. Exposed in the open.	In perfect condition.	In perfect condition, retaining its original polish, except at places where owing to bad workmanship they were not airtight.	As in preceding column.
	REMARKS—	The steel preserved in concrete showed least corrosion. It seemed to be difficult to obtain same good results in brick column. Corrosion was most marked on piece left outdoors; less so embedded in earth or kept under water.	The test-pieces embedded in concrete preserved its original condition All other situations showed gradual advance of corrosion as noted in the preceding column.	Except for places where, owing to faulty workmanship, they were not air-tight, the excellent preservative properties of concrete were indeed astonishing.

B. Changes in the Steel Materials of Different Thicknesses. Round mild steel bars of the following diameters were left in the open, exposed to the atmosphere in a dry area by the old main Engineering building of the Imperial University, Tokyo, and the effects of rust carefully noted. The steel bars were all in the form of tension test-pieces of the following diameters at the middle :—

1/8, 1/4, 3/8, 1/2, 3/4 and 1 inch.

In the present examination bars of 3/8″ and smaller were found to be entirely changed into rust. The others did not differ much from the appearances recorded in previous reports, but the rust had penetrated the surface to such an extent that it could be peeled off in scales. Detaching them by gentle tapping exposed the pitted black surface, which upon being scratched by a knife soon revealed the bright surface. After the scales were thoroughly scraped off, the bars were weighed with results as shown in annexed Table II. Photo 1 shows the appearance of the bars before and after the rust was removed.

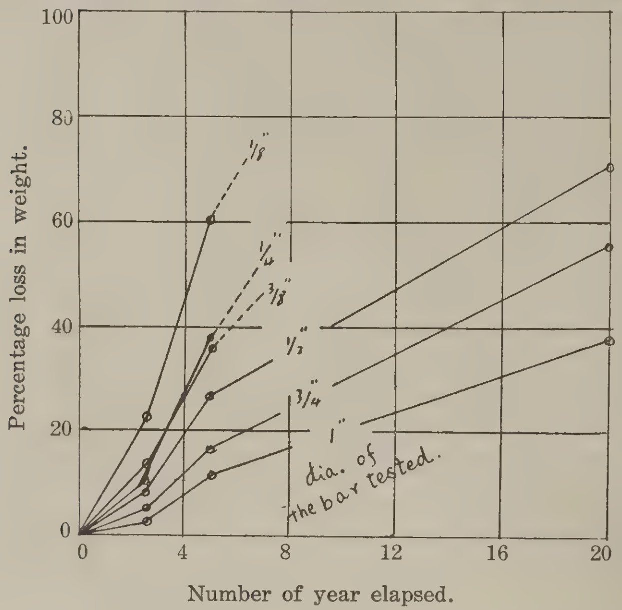
Table II.

Diameter	1/8″	1/4″	3/8″	1/2″	3/4″	1″	
Original weight of bars*	48.5	136	275	552	1077	1782	grammes.
Weights after removal of rust. Average weight of 3 bars.	0	0	0	160	580	1115	grammes.
Loss in weight	48.5	136	275	302	497	667	do.
Percentage of loss	100	100	100	71	46.1	37.2	

*These are the average weights used in the two previous reports. To consider these as the original weights of the bars in the present experiment is not quite in order, but unavoidable, owing to loss of the original records relating to the weights of the test-pieces used in the present experiments. As however the bars were polished bright we believe that the error is so slight as to be quite negligible.

The combined results of experiments B, that is the relation of the thickness of the bars to the extent of rust after periods of 2 years & 7 months, 5 years, and 20 years give curves as in the following diagram.

Fig. 1. Change in the Steel Materials of Different Thicknesses.



From the foregoing curves it is apparent that weight loss due to rust increases proportionately as the diameter of the bar diminishes, which will be obvious from the fact that as the diameter decreases, the surface area per unit volume increases with every decrease of diameter, so that the weight loss becomes proportionately greater. On this reasoning then the rate of weight loss for the same bar ought to accelerate with time, but results of our experiments do not bear this out, for on referring to the preceding figure it will be seen that the proportion of the rate of loss in the 3rd test when compared with that of the 2nd test has slightly decreased. This may be due to the protective action of the already existing rust layer against too rapid encroachment of further corrosion.

C. Value of Preservative Coatings on Steel Materials Exposed to the Atmosphere. The following five tests were made to determine the extent of rust on bars coated with paint and other preserving agents.

(g) Steel bar in the original state without any preservative coating.

(h) Steel bar polished and coated with red lead.

Table III. The Effects of Rust on Steel Materials Coated with Preserving Agents.

Test-pieces	Remarks	Results of Tests		
		1st exam' after lapse of 2 years and 7 months	2nd exam' after total lapse of 5 years	3rd exam' after total lapse of 20 years
(g) Naked state; no coating of any kind.	Bars were slightly spotted initially in places with red rust, but practically in good condition.	Growth of rust scales resembling old pine bark. Removal caused loss in weight of 9% of original weight.	Appearance as in preceding column. Weight loss 27%.	Appearance as in preceding column. Weight loss 71%.
(h) Polished and given a red lead coating.	Cleaned of rust and given two coatings of red lead.	Surface dark brown with dirt. When washed off the reddish coloured lead film, steel surface showed no changes, proving efficacy of red lead coating.	Minute spots of red rust here and there, showing that life of the protective coating had terminated.	Covered with black spots which on being washed off showed coating sound in places. Where sound the redlead was visible, but otherwise pitted and coating vanished. Weight loss 9%.
(i) Coated with cement paste.	Thickness of the pure cement paste was 3.5 mm.		Cement cracked in places parallel to direction of bar, and the portion of the bar near these cracks was rusted but in perfect condition otherwise. Hence while cement paste is a good preservative, liability to cracks curtails its usefulness.	General appearance as in preceding column, but now even at places free from cracks rust had invaded, leaving only a few bright spots on the bar. Weight loss about 9%.
(j) Coated with coal tar.	Dipped in coal-tar.	No preservative effect whatsoever. Condition practically same as that of naked bar in (g).	Outward appearance not differing materially from that of naked unpainted bar, top of this column, although weight loss here was small only about 10%.	Outward appearance much like that shown by naked bar (top of this column). Weight loss about 50%.
(k) Already rusted slightly; coated with red lead.	On the already slightly rusted test-pieces were given two coatings of red lead.	Same result as for (h).	Same result generally as (h), second in this column, but extent of rust somewhat greater.	Same result generally as in (h) but rust greater. Weight loss about 20%.

(i) Steel bar coated with cement paste.
(j) Steel bar coated with coal tar.
(k) Steel bar, slightly rusted, coated with red lead.

The general results of the examination of these tests showed that with the two previous tests, the one made after a lapse of 2 years and 7 months, and the other after 5 years, no striking changes were noticeable beyond the fact that rust had made considerable inroads on the materials. Table III annexed gives comparative results in detail of the tests made after the three time intervals mentioned. Photo 2 shows the appearances of the bar tested.

According to these results, within the limits of our experiments, red lead has proved to be the best preservative against rust but scarcely for longer period than 5 years. The value of coal-tar in these respects is exceedingly small. Cement paste is quite effective so long as cracks do not appear in the coating but as this is liable to happen with time, it cannot be depended upon.

D. Changes in the Steel Material Embedded in Concrete and also in its Preservative Coatings. In these experiments test-pieces of round mild steel bars, $\frac{1}{2}''$ dia., in conditions (l) to (p) as below were embedded in concrete blocks of composition 1:3:6, the size of the blocks being $6'' \times 6'' \times 24,''$ the whole left in the open in a dry area by the old main Engineering building of the University.

(l) Steel bar with rust scraped off.
(m) Steel bar in slightly rusted condition.
(n) Steel bar with rust scraped off and coated with red lead.
(o) Steel bar dipped in coal-tar.
(p) Steel bar coated with cement paste.

The results of these experiments, (p) excepted, were as follows:—

In (l) and (m) where the bars received no coating of any kind, preservation from rust was complete with, however, the exception of slight red spots at places where the embedding work was not carefully executed. In (n) where the bar was coated with red lead, preservation was still more complete than in (l) and (m), but the red lead film had changed to powder so that there was no contact between steel and concrete, thus showing that where steel and concrete must be used together for mutual benefit as in reinforced concrete and in steel frame concrete, the use of red lead upon steel must be prohibited. In (o) the surface of the steel was in perfect condition, but the coal-tar film had , as in the case of (n), become powdery. In this case, however, the contact between steel and concrete was closer than was the case with (n).

E. Changes in the Steel Materials Embedded in Concrete of Various Compositions. In this experiment $\frac{1}{2}''$ round test bars were embedded in concrete of various compositions in order to determine the relation of the corrosion of the steel to the particular kind of concrete employed. The concrete blocks were in every case $6'' \times 6'' \times 24''$. The mixtures stated on a volume basis were as follows :—

No. of Mixture	Cement	Volcanic ash	Lime	Sand	Gravel	Cinders
1	1			1	2	
2	1			2	4	
3	1			3	6	
4	1			5	10	
5	1		2	4	8	
6	1			2		4
7	1	1	0.25	4.5	9	

This report concerns only mixtures No. 1 to No. 6 inclusive.

These mixtures were all used in dry consistency. In the examinations made after 5 years no changes were observed in the case of mixtures 1 to 5 and 7, with a few exception of slight red spots at places where the concrete was honey combing. In the present examination made after a total lapse of 20 years, the test pieces in mixtures 1 to 3 were in sound condition, so that the preservative action of the concrete was all that could be desired. In the case of mixture 4, however, about 30%, and in the case of 5, about 10%, of the surface was covered with rust. These were due, it seems, to the concrete mixture having consisted either of improper ingredients, or in undesirable proportions, or both, resulting in air spaces in the mixture. Even in these, where the cement paste had filled every interstice, the steel bar was perfectly preserved. Again, even in the case of the first three mixtures where faulty workmanship had permitted air spaces to extend to the surface of the steel, red rust was present. Although mixture 6, the one in which cinders were used, showed considerable rust on the steel when examined after 5 years time, in the present examination 15 years later, the corrosion had reached astounding proportions, covering the entire surface of the bar, to remove which caused a weight loss of 6%. See photograph 3.

F. Changes in the Steel Materials Embedded in Concrete of Various Thicknesses. These experiments were conducted with the object of finding the extent of corrosion of steel bars embedded in concrete blocks of various sizes. The test pieces were round mild steel bars of $\frac{1}{2}''$ dia., which after having been embedded in concrete blocks of the four undermentioned sizes, were left in the open, exposed to the air outside of the old main Engineering building of the Imperial University, Tokyo.

Block No. 1. $2''\frac{2}{5}\times 2''\frac{2}{5}\times 24''$
,, No. 2. $6''\times 6''\times 24''$
,, No. 3. $12''\times 12''\times 24''$
,, No. 4. $24''\times 24''\times 36''$

The present examination covers only blocks 1, 2, and 4. When these were examined after a lapse of 5 years, all of them, excepting those in which the embedding was faultily executed, were found to be in a state of perfect preservation. In the present examination, that is 15 years later, or a total period of 20 years, those blocks in which the embedding was faulty showed great inroads of rust. Where the concrete was not very thick, as in the $2''\frac{2}{5}\times 2''\frac{2}{5}\times 24''$ block, the bar was quite rusted and expansion had caused longitudinal cracks in the concrete along the reinforcement as shown in photo. No. 4. The reinforcement of the $6''\times 6''$ block was unaffected. Lastly on examining the 24″ block, we found things in a state other than we had expected, the extent of rust covering about 10% of the entire surface. The cause of this rust was found to be due to interstices that had been allowed to form in the process of placing concrete, thus permitting the surface of the steel to come in contact with the air.

3. RESULTS OF EXPERIMENT SERIES II.

The object of these experiments was to study the extent of corrosion of steel embedded in concrete, and they therefore supplement experiment series I reported in the foregoing pages. Particular attention was paid to the relation of corrosion to the manner of workmanship, that is in the reinforcing.

In the first series of experiments the mixture of the concrete was 1:3:6, but the proportion in the present case was 1:2:4, and, owing to the superiority of the latter coupled with the special care used in reinforcing so as to secure airtightness, not the slightest signs of honey combing could be detected, thus showing that the test was made under ideal conditions. In these respects our experiments series I were not satisfactory, since, as already stated, the reinforcements in favourable cases were sound, whilst in others where they were not airtight, rust had attacked the steel. The present series of experiments were quite free from such defects in workmanship.

The concrete used was of the ratio 1:2:4 and three kinds of aggregates were used, thus

(a) Ordinary gravel.
(b) Brick fragments.
(c) Cinders.

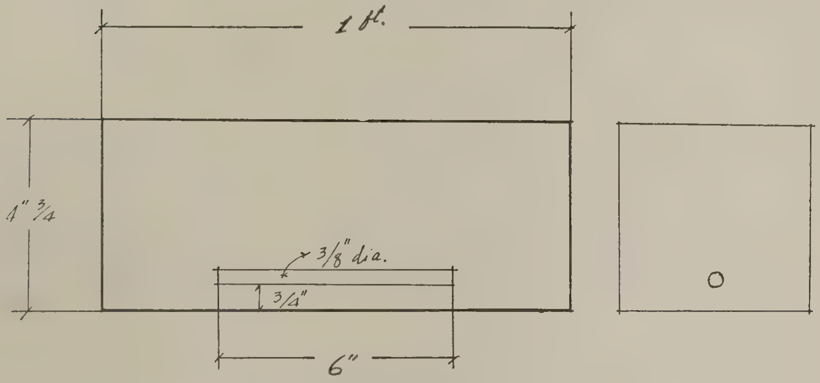


Fig. 2. Size of Test-piece of Expt. Series II.

These were made into blocks of shape shown in Fig. 2 and into each of which round mild steel bars of 3/8″ dia. were inserted. The bars were different to those used for experiment series I in that these were ordinary rolled bars, neither turned nor filed, being the ordinary rolled bars with the "roll skins" on them. The reinforced blocks were then placed in the following situations,

(1) In the open.
(2) Underground.
(3) Under water.

Unfortunately, however, (2) and (3) were lost so that our investigation is confined to the block which was placed in the open.

On breaking then the three concrete blocks (a), (b), and (c) which had been left in the open for 15 years, the reinforcements were found to be quite intact, just as they were on the day they were placed in the concrete: an eloquent testimony to the good workmanship.

In contrast to the very poor results shown by the cinder-concrete in experiment series I, the tests in the present case gave very good results, because, in addition to the reasons already given, the cinders used this time were carefully selected and then washed with water. It would seem that omission of these precautions had much to do with the poor results of the previous experiments. By washing, all acidity had been removed from the cinders and as the fine particles had also been eliminated, the concrete was made compact. Thus we know even in the case of aggregates consisting of cinder as well as of brick fragments, the reinforcement will remain its original appearance even after a lapse of this long time of test, *provided the quality of the aggregates and the mode of treatment has been proper.*

4. CONCLUDING REMARKS.

These experiments having been devised and initiated as far back as 15 to 20 years ago, we are not altogether without some misgivings as to the propriety of the methods employed by us in attacking the problem. On the other hand we are conscious that the very general nature of our methods enables application of the results obtained to general present day problems. We shall now state our conclusions on the results of our observations.

A. That steel left in the open exposed to air will soon rust is too well-known to need repetition, but our researches have thrown some light on the way in which the action takes place. Rust, at all events, never attacks steel in an even manner over the surface, but gradually pits the surface so that it is no more even but full of little elevations and depressions.

To ascertain the rate of advance of this rusting process the surface of a round bar of, say, 1″ section was assumed to be a flat surface and the thickness of the rust film was calculated from the extent of rust undergone in the 20 years, when it was found that the average rust per annum worked out to a thickness of 0.15 mm. Bars of 3/8″ and smaller had in this long period rusted right through with no more steel left. From these examples it will be possible to work out the rate of time taken by rust to reach a certain stage.

B. In the matter of preservative coatings, as far as our experiments went, red lead has proved to be the most efficaceous, although, prior to its application the surface to receive the coating must be thoroughly cleansed of any rust already existing. With our tests its life was 5 years, but with the great improvements since then in the paint manufacturing industry, and with reasonable care exercised in its application, a longer lease of life may be expected.

The efficacy of coal-tar for any length of time is not to be expected. Cement paste is a good preservative, provided the paste is applied in such a manner as to render it airtight, but owing to its liability to crack and permit air to reach the steel surface, it cannot be depended upon for any length of time.

C. In the process of reinforcing the steel must on no account be coated with red lead and such, because they interfere with the desired adhesion of the steel to the concrete matrix.

D. To preserve steel material encased in brick masonry from rusting is extremely difficult.

E. The changes suffered by steel reinforcements in the concrete is an important matter in structural engineering practice. The prevailing opinion seems to be that steel in a concrete matrix is immune from rust. At the time these experiments were initiated the question to us was one of general doubt, but thanks to the tests, some doubtful points have been cleared. The marvellous protective properties of concrete were amply demonstrated. Even with an inferior mixture like 1:3:6, so long as the workmanship was done properly, the steel retained its original lustre until the end of this long period of time, so that with concrete of 1:2:4 and due care exercised to ensure good workmanship, excellent results were obtained as above recorded.

At the same time too implicit faith in the preservative properties of concrete ought to be guarded against. Generally speaking, the chemically neutral state and acidity are both conducive to rust development, while alkalinity has the very reverse tendency. Cement on dissolving in water liberates a large quantity of calcium hydroxide, making the concrete partake of a strongly alkaline character. It is this calcium hydroxide that is the fundamental rust preventative, but with prolonged exposure of the concrete to the atmosphere, the calcium hydroxide changes by the action of the carbon dioxide in the atmosphere to calcium carbonate, the change working by stages into the interior of the concrete. Upon now breaking up any of these blocks and dropping on to the section some Phenolphthalein solution the central part assumes a deep red colour which, however, does not extend right up to the margin of the fractured surface, a proof that the concrete is losing its alkalinity from the central part towards the margin.

Photos No. 6, 7, 8 and 9 show sections of concrete in the manner just mentioned. They are the concrete blocks of different compositions alluded to in paragraph D, experiments series I. For these sections the parts showing good workmanship in reinforcing were selected. The thickness of such parts as alter to carbonate will obviously depend on the original concentration of the cement paste so that considerable variation in the extent to which the change takes place must be expected according to the composition of the concrete. In this experiment the mean thickness of the carbonated portion in accordance with the composition of the concrete mixture is shown in the table which follows.

Table IV. Depths to which the concrete lost its alkalinity. Age of material 20 years.

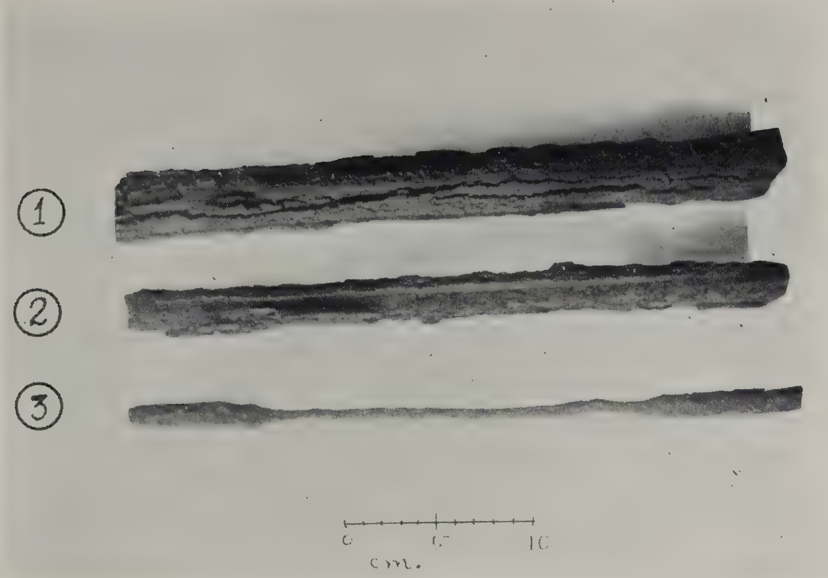
Composition of concrete	Thickness of part neutralized	Remarks
1 : 1 : 2	0.65 cm.	Owing to loss of the detailed records covering the concrete, it is not possible to know the exact water-cement ratio or other data.
1 : 2 : 4	1.39	
1 : 3 : 6	3.33	
1 : 5 : 10	4.32	

The alkalinity of the concrete gradually disappears in the manner above shown. According to our observations, such parts of the reinforcements that were invariably rusted showed that the concrete in contact with it had already lost its alkalinity, whereas the concrete matrix surrounding such parts of the steel as retained its original brightness, was still alkaline. On the whole, even in blocks where the central portion was still alkaline, at places where air had penetrated deeply through interstices in the matrix, neutralizing of the concrete had advanced so that that parts of the steel surface in contact with it were bound to be rusted. This was frequently noticed in our first series of experiments, which as we have explained before, was due to unsuitable concrete mixtures and to faulty reinforcing.

F. On examining the effects in concretes where light aggregates were used, results were very unsatisfactory as in the case of the cinder concrete of experiment series I; the steel in most cases being completely rusted. This is because the cinder was not thoroughly washed before use, consequently holding small ash particles, resulting in more or less porosity of the concrete. Acidic components in the cinders also contributed their quota of deleterious effects. In the cinder-concrete that was used for the first series hardly any part of it showed alkaline reaction with phenolphthalein, whereas the cinder concrete used in the second series gave excellent results, due, apparently to previous washing of the cinders. In this concrete, while such parts of it as consisted mainly of aggregates were porous, the mortared parts were compact which accounts for the good results.

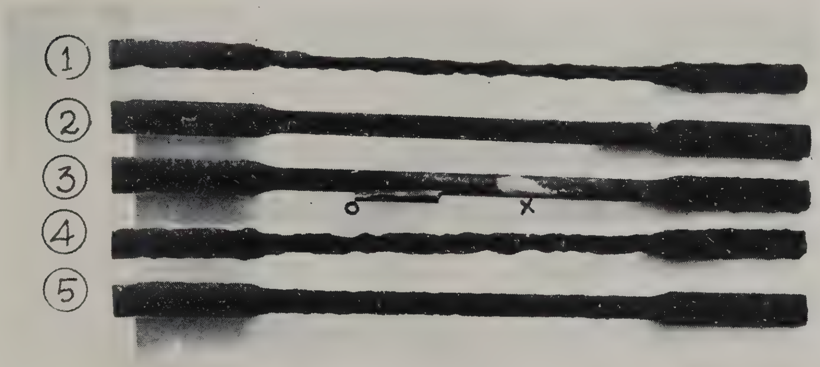
The brick fragment concrete used in series II also gave excellent results. On testing the fractured surfaces of these with phenolphthalein the depth of the neutral portion was found to be very small as shown in photos No. 10 and 11.

Photo. 1. Size of steel material versus rust.



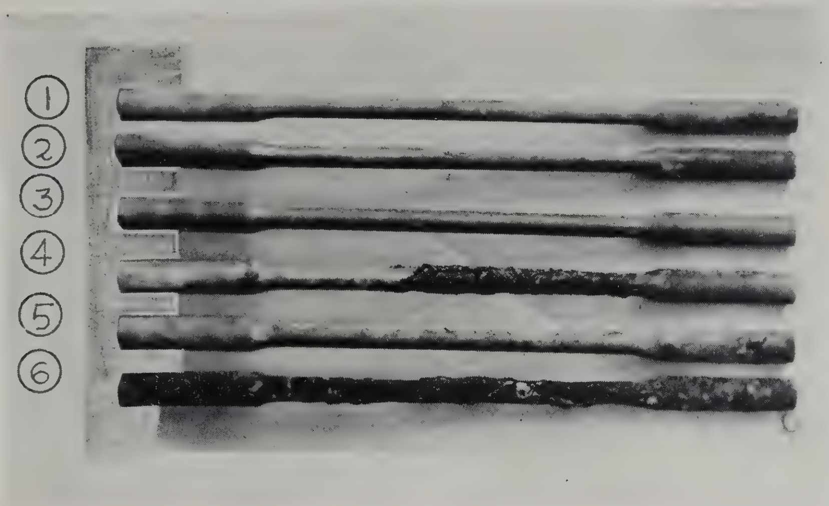
(1) Appearance of steel bar 1″ dia. left exposed in the open for 20 years showing the old pine-bark like rust scales.
(2) do. but 3/4″ dia. Some of the rust scales detached.
(3) do. but ½″ dia. All the rust scales scraped away.

Photo. 2. Changes in the steel materials coated with preserving agents and exposed to the atmosphere.



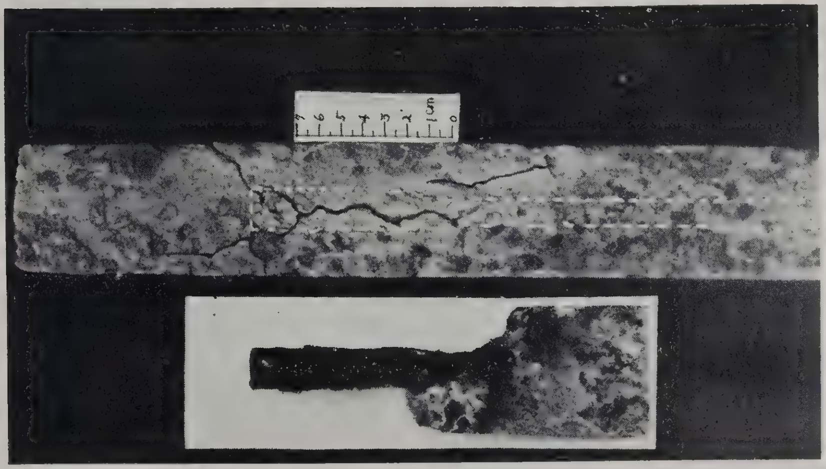
(1) Steel bar ½″ dia. without any preservative coating, exposed in the open for 20 years. Rust scales scraped away.
(2) do. but this bar was originally polished and coated with redlead.
(3) do. do. do. do. coated with cement paste. (○) shows a bit of the cement film, the rest of it having been scraped away. At (×) the film was adhering firmly to the steel, which on removal shows the bright steel surface.
(4) This bar had been dipped in coal-tar.
(5) This bar was already rusted slightly over which coatings of red lead were given.

Photo. 3. The nature of the concrete versus rust.



(1) Steel bar, ½″ round, that had been embedded in concrete 1:3:6 block 6″×6″ and left in the open for 20 years.
(2) do. but concrete (1:2:4)
(3) ,, ,, (1:3:6)
(4) ,, ,, (1:5:10)
(5) ,, ,, (1:2 lime:4:8)
(6) ,, ,, (1:2:4 cinder)

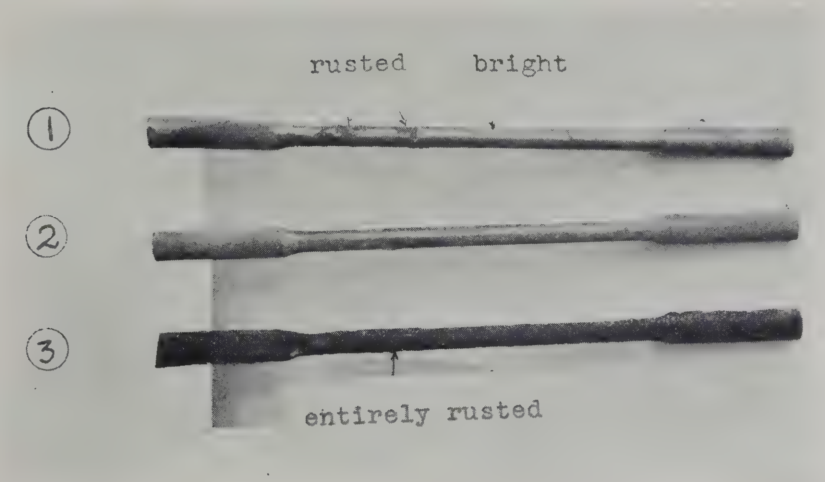
Photo. 4. Cracks in concrete caused by rusting of steel.



Above. Appearance of concrete block (1:3:6), 2″2/5×2″2/5, in which a steel bar of ½″ dia. was embedded and then left in the open for 20 years. White broken lines indicate position of the steel reinforcement. Note cracks in the concrete.

Below. As above. Part of the top concrete removed. The steel bar was quite rusted.

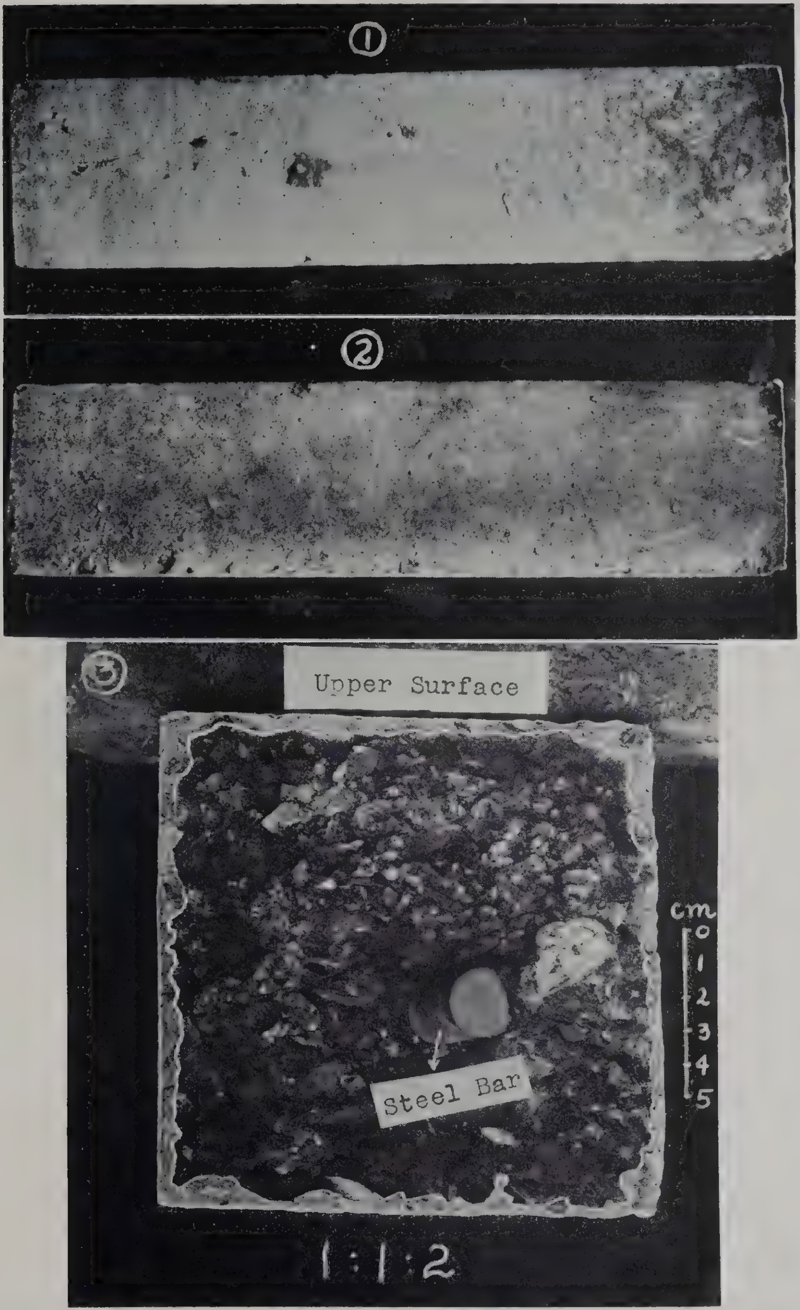
Photo. 5. Thickness of the concrete versus rust.



(1) Mild steel bar, ½″ round, which was embedded in concrete block (1:3:6) 24″ square, and left exposed in the open for 20 years.
(2) do. but size of block 6″×6″.
(3) ,, ,, ,, ,, 2″2/5×2″2/5 (entirely rusted).

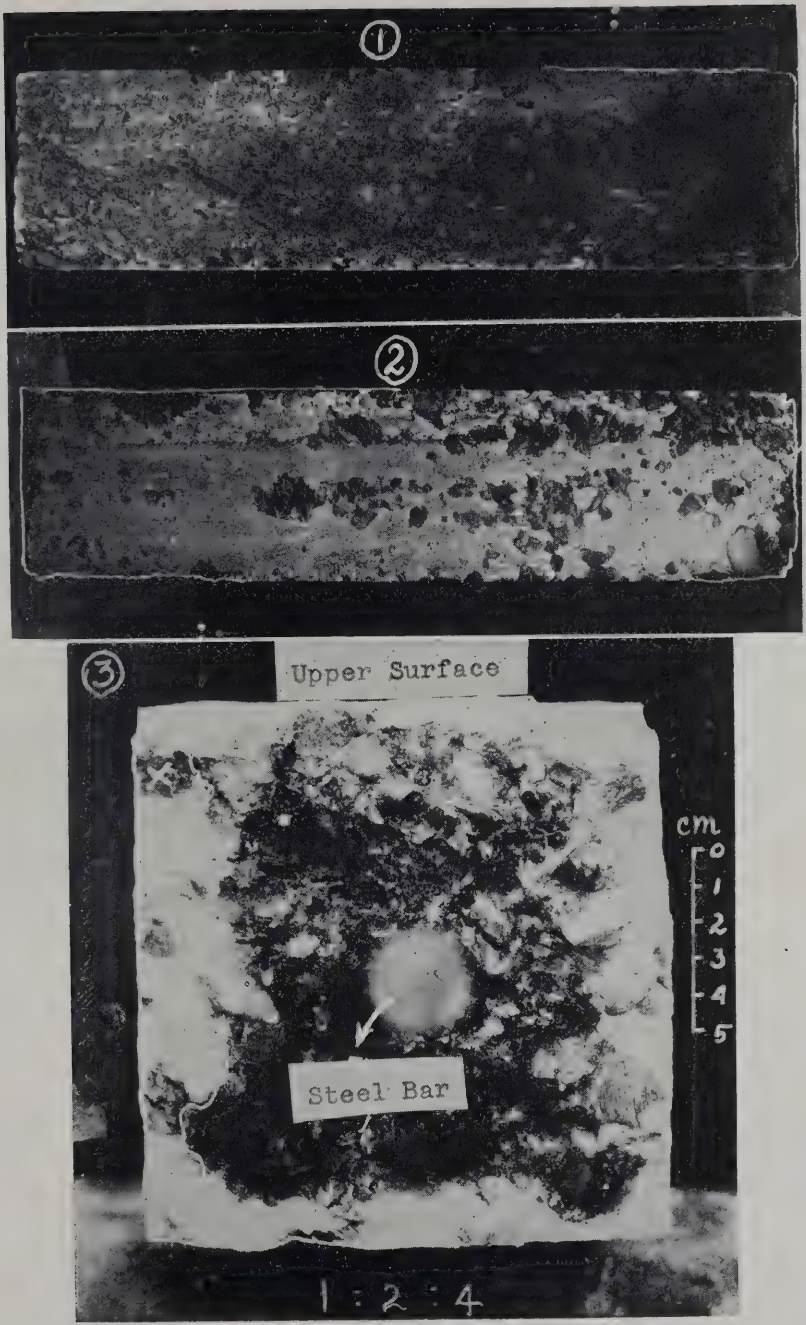
Dark portions are rusted while fair parts are bright.

Photo. 6. Disappearance of alkalinity in concrete of mixture 1:1:2.



Concrete block (1:1:2), 6″×6″, left in the open for 20 years.
(1) Upper surface at time of tamping.
(2) Side do. do. do.
(3) Phenolphthalein applied to surface of section. Discoloured part shown off by white boundary lines. Aggregates are crossed where line is broken.

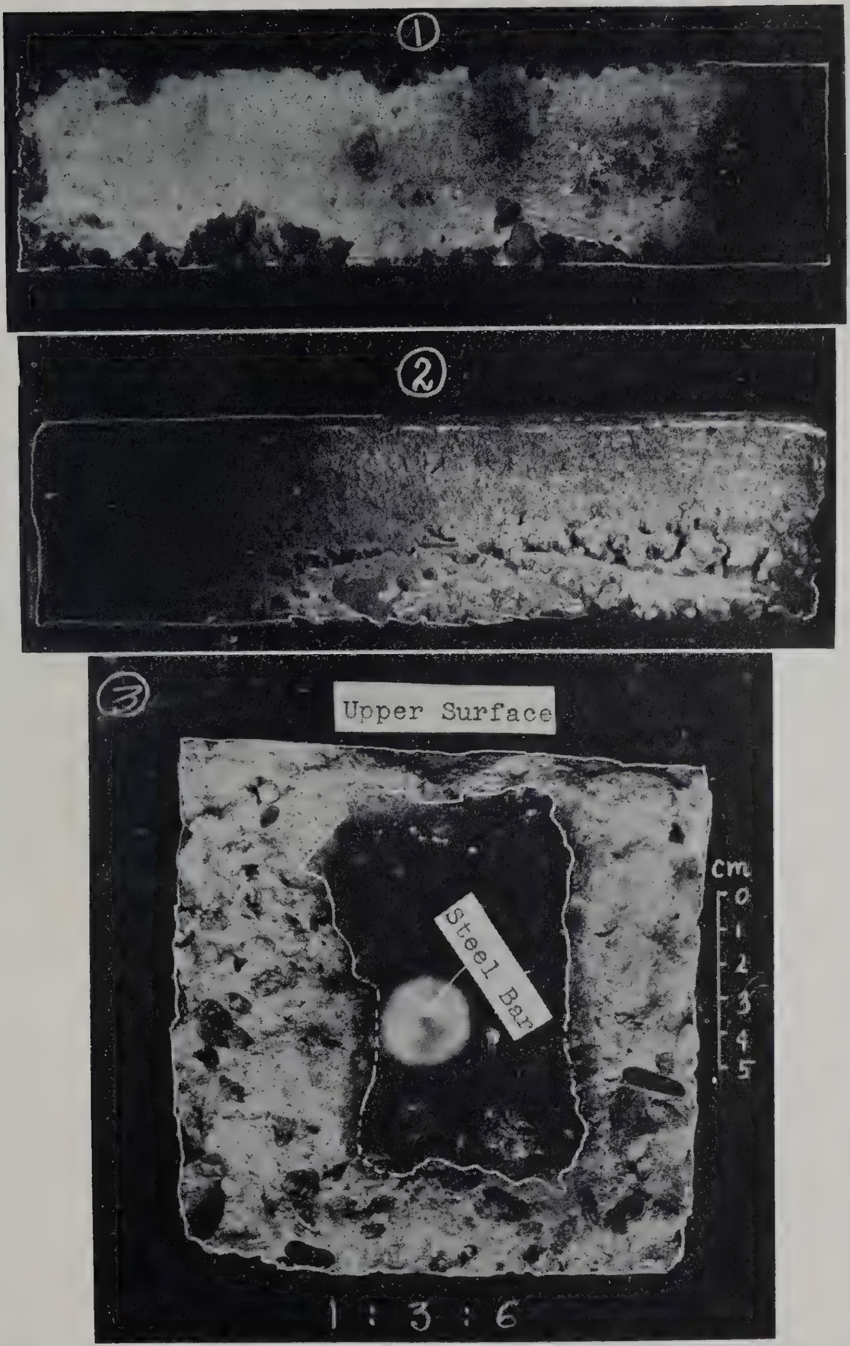
Photo. 7. Disappearance of alkalinity in concrete 1:2:4.



Concrete block (1:2:4), 6″×6″, left in the open for 20 years.

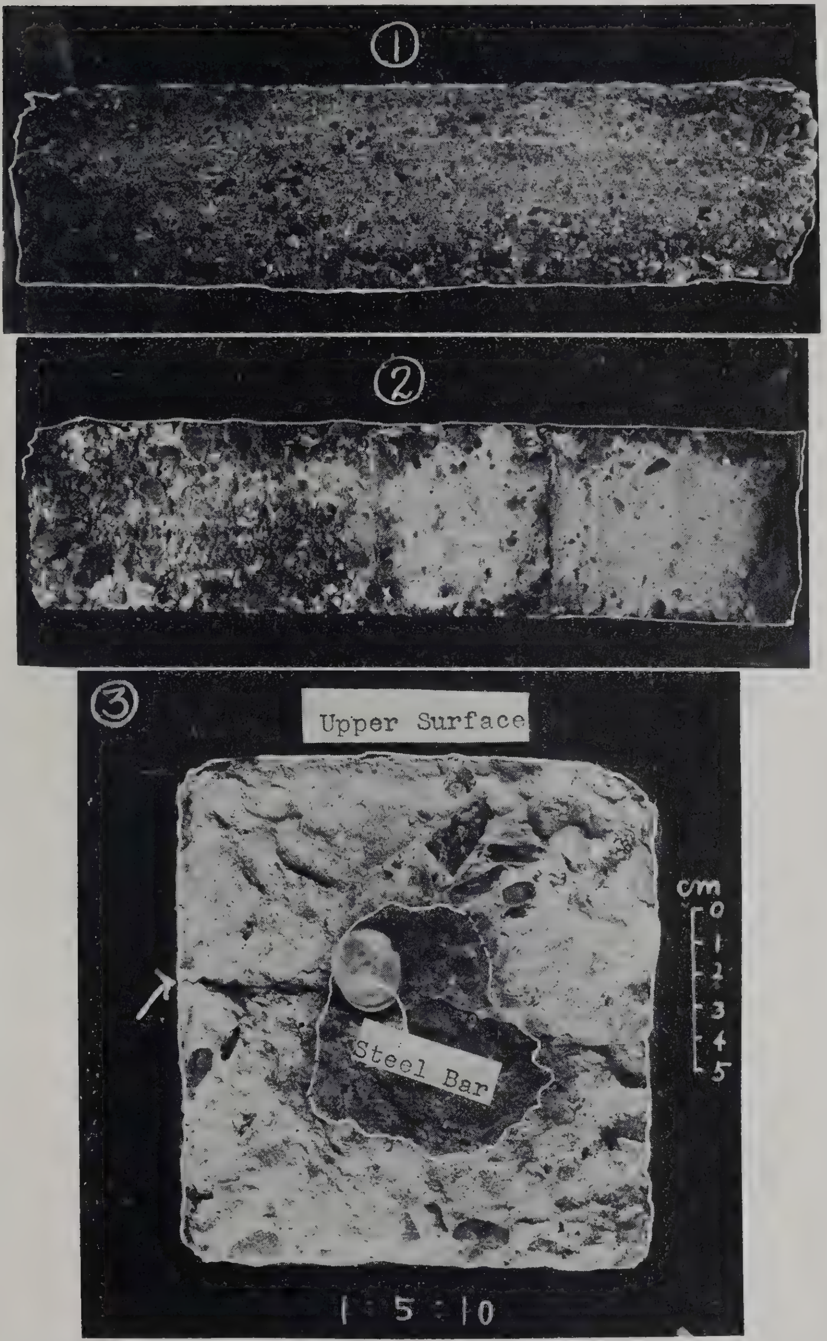
(1) Side surface at time of tamping.
(2) Bottom do. do.
(3) Phenolphthalein applied to surface of section. White lines to mark off the discoloured boundary. Aggregates are crossed where line is broken. Cross (×) shows aggregate and is not portion coloured by phenolphthalein.

Photo. 8. Disappearance of alkalinity in concrete 1:3:6.



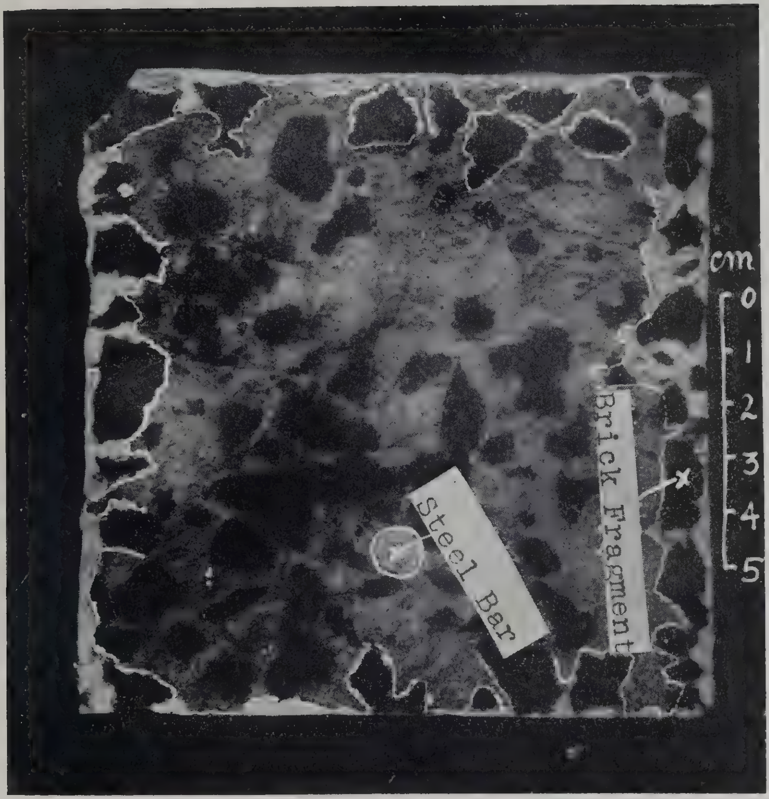
Concrete block (1:3:6), 6″×6″, left in the open for 20 years.
(1) Bottom surface at time of tamping.
(2) Side do. do.
(3) Phenolphthalein applied to surface of section. White lines to mark off discoloured boundary. Aggregates are crossed where line is broken.

Photo. 9. Disappearance of alkalinity in concrete 1:5:10.



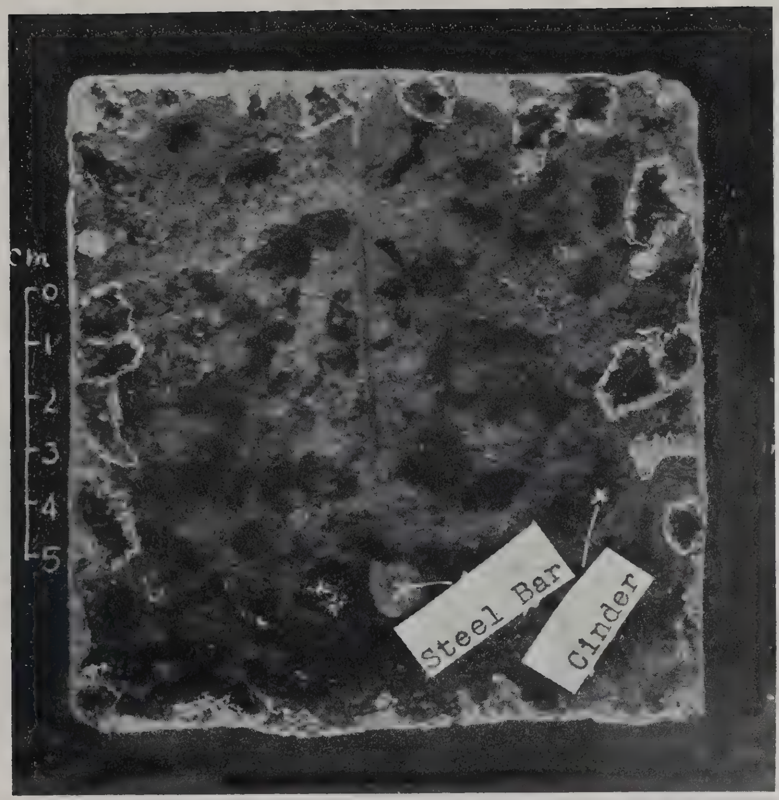
Concrete block (1:5:10), 6″×6″, left in the open for 20 years.
(1) Side surface at time of tamping.
(2) Bottom do. do.
(3) Phenolphthalein applied to surface of section. White line to mark off discoloured boundary. Aggregates were crossed where line is broken. Arrow indicates where crack occurred when section was being cut.

Photo. 10. **Brick-fragment concrete.**



Effect of phenolphthalein solution on surface of freshly cut section of brick-fragment concrete block (1:2:4), 4″3/4×4″3/4 left in the open for 15 years. Note that the white line has penetrated deeply only along the brick-fragments found near the surface.

Photo. 11. Cinder-concrete.



Effect of phenolphthalein solution dropped on to fresh surface of section of cinder-concrete block (1:2:4), 4″3/4×4″3/4, which was left in the open for 15 years. Note that the white line has penetrated deeply only along the cinder found near the surface.

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印刷者　笠井重治

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BULLETIN

OF THE

IMPERIAL
EARTHQUAKE INVESTIGATION
COMMITTEE

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		Page.
F. OMORI.	Pheasant as Seismoscope....	1–5
,,	Successive Occurrences of Destructive Earthquakes. ...	7–24
,,	Focal Depth of the Earthquakes originating in the Kwanto Provinces.	25–27
,,	Earthquake Zones in and around the Pacific.	28–32
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Tokyo. March, 1923.

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Tokyo. March, 1923.

Pheasant as Seismoscope.

By

F. OMORI.

With Plate I.

Introduction. Certain animals are known to show symptoms of terror at the time of an earthquake. I have noticed on several occasions during night that the frogs croaking musically became suddenly quiet just before or at the moment of an earthquake. If the shock be strong, there is caused a general noisiness, and cocks crow and dogs bark. In the strong Omachi (Shinano) earthquake of Nov. 11, 1918, at 4. 03 P.M., the abbot of the Buddistic temple Daitakji （大澤寺） was at the time riding in the vicinity of the village of Sanga-mra （三日村), to the north of Omachi, and found his horse suddenly dropping flat on the ground; no whipping of the rider, who did not at once realize the earthquake shock and was at a loss to guess at the cause of this strange behaviour, being able to set the animal again on foot till the shaking was over.

In Japan there is a general belief that the pheasant (*Phasianus versicolor*) perceives the earthquake earlier than ourselves, such that it crows some time previous to the actual occurrence of the sensible movements. That the pheasant should be very sensitive and take alarm at the slightest disturbance, either natural or artificial, is probably a condition necessary for its existence, as the bird with a long pointed tail and comparatively small wings, has not high flying capacity, and nestles on the ground among the thick underwood. My preliminary remarks on the seismic sensibility of the pheasant was given in No. 68, A of the Japanese Reports of the Imp. Earthq. Inv. Comm. (1910)[*]. Since then, during my residence of three years, 1913 to 1916, at Sekiguchi-daimachi, in the Koishikawa ward, at the north-western end of the city, I had the fortunate opportunity of noting the crowing of the pheasant during night which inhabited the neighbouring spacious garden of the former mansion of Count Tanaka. As I sat writing or studying quietly, often till 2 A.M., I could perceive very slight earthquake shock, whose time of occurrence was accurately noted by a pocket chronometer-watch placed in front on the desc, and compared with the time at which the pheasant crowed. It was found that the pheasant, which generally well crowed at the times of the earthquakes, gave very rarely signs of alarm at the passage in the neighbourhood of the motor-cars and goods-wagons, although these often caused shakings of the ground and the houses to a fairly distinct amount.

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[*] The late Professor S. Sekiya kept for some months a pheasant in the Seismological Institute, then at Hitotsubashi, and tried to observe the behaviour of the bird at the time of the earthquakes. No definite conclusion was then reached at. Dr. Y. Tsukiji's note on the times at which the pheasants crow generally is given in the Toyo Gakugei Zasshi, Vol. 27, (1911).

As is well known, every earthquake begins with the preliminary tremor composed of small movements, whose duration, proportional to the distance from the seismic origin, varies, for cases of the sensible shocks, from practically zero to about 1 minute. From the following account of my experiences it is obvious that the pheasant is often very sensitive to the earthquake motion and takes alarm at the mechanical perception of the preliminary tremor. The distance between the pheasant and the observer (author) in the different cases probably varied between a few metres and about 100 metres.

OBSERVATIONS.

(1). Dec. 31, 1913; 0. 56. 15 A.M. The house creaked in a scarcely audible degree, thereupon the pheasant crowed twice. Five seconds later slight but distinct shaking was felt for one second.

(2). Feb. 12, 1914; 3. 58. 57 A.M. The preliminary tremor lasted 7 or 8 sec. The pheasant crowed.

(3). Feb. 25, 1914; 10. 21. 01 P.M. The pheasant crowed thrice successively, thereupon slight shaking was felt for 25 seconds.

(4). March 5, 1914; 9. 39. 39 P.M. Suddenly there was perceived a loud sound like that caused by the falling of a heavy weight on the ground, accompanied by vertical tremors. 17 seconds later on the shaking became stronger, and the pheasant crowed first only after the lapse of further 4 seconds. The sensible motion lasted till 9. 40. 25 P.M.

(5). Aug. 3, 1914; 8. 59. 58 P.M. There was first perceived a slight sound (*ton*) like that of a foot tread, which I believed to be the announcement of an earthquake. 5 seconds later on sharp vertical movements were felt for a short time interval, when the pheasant crowed two or three times.

(6). Nov. 24, 1914; 8. 56. 58 P.M. There were first the crowings of the pheasant for a short time interval, and then slight tremors were perceived.

(7). May, 19, 1915; 5. 40. 25 A.M. The motion was moderately strong and the house was shaken with cracking noise, the duration of the sensible earthquake being 35 sec. The pheasant first crowed 16 sec. after the commencement.

(8). May 25, 1915; 9. 41. 12 P.M. The pheasant crowed twice, and 1 sec. later slow slight movement was felt.

(9). July 2, 1915; 10. 37. 31 P.M. The motion was composed of moderately pronounced horizontal shaking, whose preliminary tremor lasted about 10 sec., and whose total duration was $1^{m}\ 20^{s}$. The pheasant crowed at the commencement of the earthquake.

(10). May 29, 1916; 11. 41. 43 P.M. There were felt first very slight tremors, and 1 sec. later the pheasant crowed. The total duration of the sensible motion was 55 sec.

(11). June 10, 1916; 10. 03. 15 P.M. There were felt very slight movements, at the same time the pheasant crowing twice. The sensible motion lasted 10 sec.

(12). Aug. 11, 1916; 1. 01. 56 A.M. The pheasant crowed first, and 5 seconds later very slight horizontal motion was felt, lasting 34 sec.

(13). Aug. 21, 1916; 10. 09. 10 P.M. The pheasant crowed, but no motion was felt, the tromometers indicating also no earthquake. At 11. 21. 08 P.M., on the same day, the pheasant again crowed and this time slight horizontal motion was felt 6 seconds later on.

(14). Aug. 21, 1916; 11. 34. 17 P.M. There was felt first slight vertical tremors, the pheasant crowing at the same time. According to the tromometer registers, the preliminary tremor lasted 12 sec., and the total duration was $1^{m}\ 13^{s}$.

(15). Aug. 24, 1916; 10. 12. 42 P.M. The pheasant crowed, and very slight shaking was felt for 15 sec.

(16). Aug. 26, 1916; 10. 47. 00 P.M. The pheasant crowed, but no shaking was sensible. There was, however, a small earthquake on the tromometer registers, whose maximum motion was about 0.028 mm. and of period=0.32 sec. (See fig. 2, Pl. I.)

(17). Aug. 28, 1916; 0. 42. 55 A.M. There was first perceived a faint sound, the *shoji* (paper-covered sliding doors) making very slight rattling. As there was at the time no wind, this was understood to be the commencement of a small earthquake, but it was 3 seconds later on that the pheasant crowed, the motion becoming sensible at the same time and lasting for 35 sec.

(18). Aug. 28, 1916; 7. 45. 20 A.M. The pheasant crowed first, and the motion was felt 5 seconds later on. After a further interval of 15 sec., the shaking became stronger. The total earthquake duration was $1^{m}\ 20^{s}$.

(19). Sept. 1, 1916 ; 10. 28. 08 P.M. The pheasant crowed, but no motion was sensible. The tromometers, however, registered at the time in question an exceedingly small earthquake.

(20). Sept. 1, 1916 ; 11. 21. 38 P.M. The pheasant crowed first, and 8 sec. later on the earthquake motion became sensible, lasting 32 sec. At 11. 23. 11 P.M., the pheasant crowed again, but no motion was sensible.

(21). Oct. 2, 1916 ; 1. 12. 28 A.M. There was felt the shaking of the house, which was so exceedingly weak that I was not able to ascribe it positively to the effect of an earthquake. The pheasant did not crow, but the tromometers registered a very slight tremor at the time in question.

(22). Oct. 25, 1916 ; 9. 24. 27 P.M. The pheasant crowed loudly several times, but there was no sensible earthquake motion*. According to the tromometer registers there was a distant earthquake whose preliminary tremor lasted 32 sec. The time instant when the pheasant crowed was 44 sec. after the commencement of the earthquake, or 12 sec. after the commencement of the principal portion.

(23). Nov. 7, 1916 ; 6. 33. 04 P.M. The pheasant crowed several times with some intervening time intervals. There was no sensible motion. The tromometers, however, registered simultaneously a very small earthquake, whose maximum motion was only about 0.011 mm. and of period=0.24 sec. (See fig. 1, Pl. I.)

SUMMARY. The comparison of the time of earthquake occurrence and the instant of the pheasant crowing in the 23 cases above described is as follows :—

(i). 5 cases (Nos. 1 ; 2 ; 9 ; 11 ; 14). The perception of the earthquake motion was nearly simultaneous with the crowing of the pheasant.

(ii). 7 cases (Nos. 3 ; 6 ; 8 ; 12 ; 13 ; 18 ; 20). The pheasant crowed previous to the occurrence of the sensible earthquake motion.

(iii). 4 cases (Nos. 16 ; 19 ; 22 ; 23). The pheasant crowed, but the earthquake motion was too small to be sensible.

(iv). 5 cases (Nos. 4 ; 5 ; 7 ; 10 ; 17). The pheasant crowed later than the arrival of the sensible earthquake motion.

(v). 1 case (No. 21). The earthquake was sensible, but the pheasant did not crow.

Thus, (i), in 20% out of the total number of cases the pheasant crowed almost simultaneously with the sensible earthquake motion. (ii), in 34%

---

* My assistant, Mr. H. Krosaka felt the earthquake slightly in an upstair room of a house in the soft made-ground portion of the Sendagi-cho, in the Hongo Ward.

the pheasant crowed earlier than the occurrence of the sensible motion, the time difference varying up to 8.0 sec., with the mean value of 3.6 sec. (iii), in 20% the pheasant crowed even in cases in which the earthquake motion was too small to be sensible to us. Altogether in approximately 50%, (ii) and (iii) combined, the pheasant has felt the earthquake motion better than I could while sitting quietly in the depth of night.

(iv), in 20% of cases, the pheasant crowed later than the occurrence of the sensible motion, the time difference varying up to 21 sec., with the mean of 9.2 sec.

The keen perception by the pheasant of the earthquake occurrence is no doubt due to their acute sense, by which it is enabled mechanically to feel the small vibrations in the preliminary tremor stage of the seismic motion. In some cases as in (iv), however, the pheasant crowed several seconds after I had felt the motion; in a special instance, No. 22, the pheasant having crowed 44 sec. after the actual commencement of the earthquake recorded by the tromometers.

The monthly distribution of the different earthquakes at which the pheasant crowed is as follows:—

Month.	Eqke. Frequency.	Month.	Eqke. Frequency.
I	0	VII	1
II	2	VIII	8
III	0	IX	2
IV	1	X	1
V	3	XI	2
VI	1	XII	1

This distribution, though having no claim to any degree of generality, may be taken as indicative of the fact that the crowing of the pheasant observed was really the effect of the alarm at the seismic disturbance, not influenced by circumstances of breeding of the bird which usually takes place in March.

E.W. Component Tromometer Diagrams at Hongo of the Unfelt Earthquakes signalled by the Pheasant's Crowing.

d......Earthquake commencement.

s......Principal portion

×......Time (minute) cutting.

t......Time tick (minute) mark.

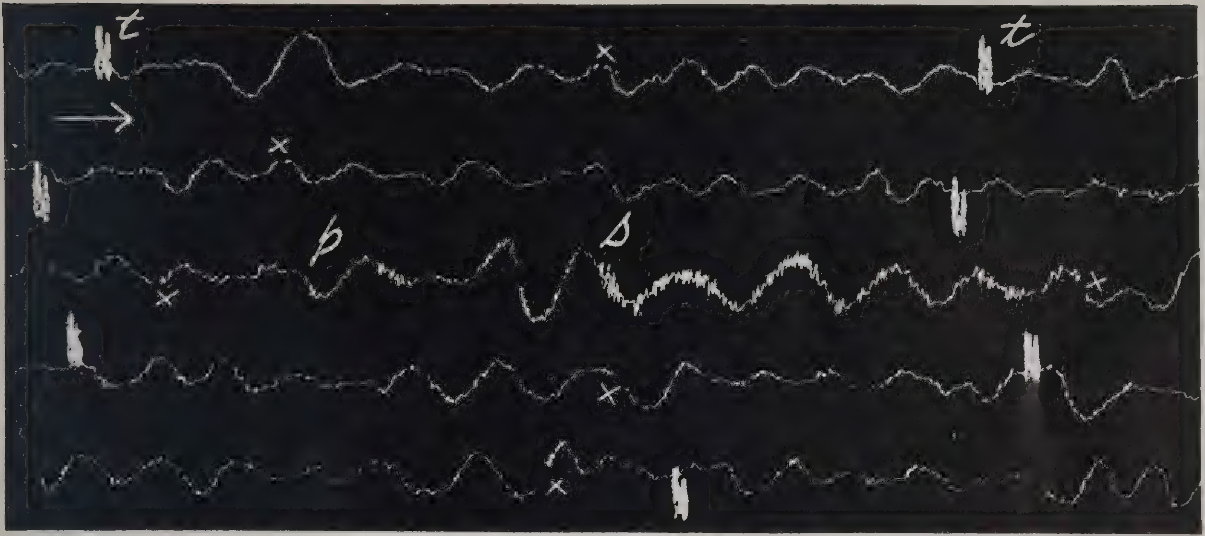

Fig. 1. Nov. 7, 1916 ; 6.33 P.M. Magnification = 537.

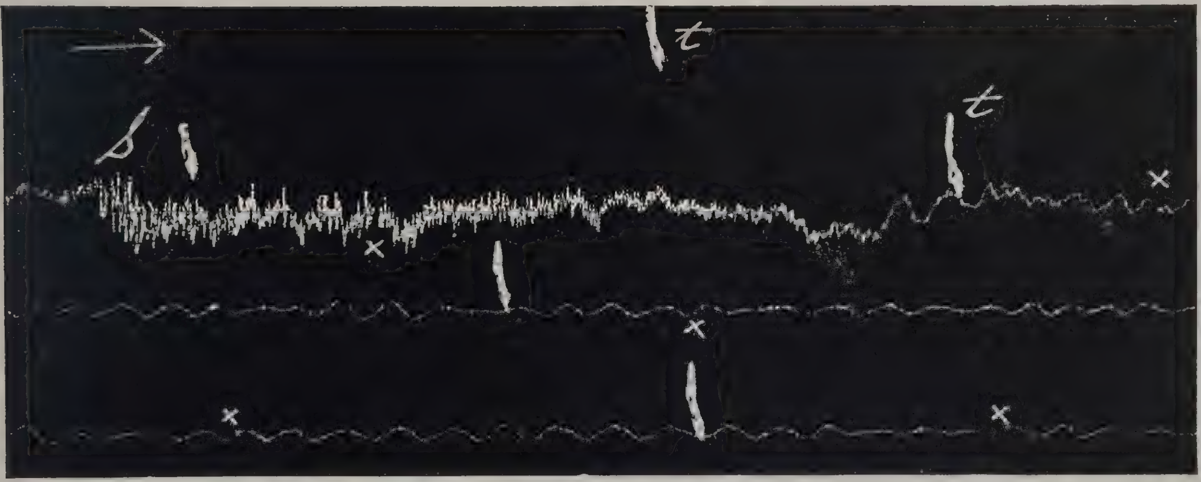

Fig. 2. Aug. 26, 1916 : 10.47 P.M. Magnification = 487.

On the Successive Occurrences of Destructive Earthquakes.*

By

F. OMORI.

With Plates II and III.

1. Introduction. This note gives an account of the successive occurrences of large and small destructive earthquakes in Japan. The repetition may take place within a small area or at wide distances along a great seismic zone, according to the magnitude of the destructive disturbances.

2. Earthquake zones and districts. The group of the Japanese islands of Hokkaido, Main Island, Shikoku, and Kyushu, forms a well defined insular arc, whose outer, or convex, side borders on the deep Pacific basin, and whose inner, or concave, side is continued to the shallow Japan Sea. This Japan Arc is continued to the equally remarkable Kurile and Lyukyu arcs on the north and on the south-west respectively. It is natural that an accumulation of stress along these great arcs should result in the production of an active seismic epoch throughout the whole system and cause the successive occurrences of destructive shocks from different parts of the country. A most remarkable instance of this sort is furnished by the group of the 12 Ansei period earthquakes, including, amongst the others, the Odawara earthquake of 1853; Iga, Ise, and Nara earthquake on July 9, 1854; the Tokaido, the Nankaido, and the West Inland Sea earthquakes respectively on the 23rd, the 24th, and the 26th, in December of the same year; and the Yedo earthquake on Nov. 11, 1855. In recent times, the semi-destructive Kmamoto (Kyushu) earthquake of 1889 was quickly followed by the great Mino-Owari earthquake of 1891; the Noto earthquake of 1892; the Kagoshima earthquake on Sept. 7, 1893; the Nemro and Kshiro (Hokkaido), the Tokyo, and the Sakata earthquakes respectively on March 22, June 20, and Oct. 22, in 1894; and the earthquake and *tsunami* (tidal waves) of Sanrik (three provinces of

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Rikzen, Rikchu, and Mutsu), and the Rik-U (Uzen and Rikchu) earthquakes respectively on June 15 and Aug. 31, in 1896.

The great Mino-Owari (Central Japan) earthquake of 1891 was due to the formation of an extensive dislocation transverse to the Main Island, and the Tokaido and Nankaido earthquakes of 1854 were probably due to the longitudinal dislocations formed off the Pacific coast of Japan. In other words, these earthquakes were great non-local seismic disturbances having tectonic relations with the whole Japan Arc. On the other hand, the Asama and the Hakone earthquakes of volcanic nature, the earthquakes with *jinari* (earth sound) of the Arima district (near Kobe), and the shocks so often happening from the Awa-Kazusa peninsula and the neighbourhood of Mount Tsukba are small local disturbances originating in limited seismic districts. The successive occurrences of great non-local earthquakes may take place from different parts of an extensive seismic region, as the Japan arc, while those of small local earthquakes may take place from different points within a given local seismic district. I enumerate below the cases of the successive occurrences of strong earthquakes within one and the same district and those from widely distant places.

3. Small destructive shocks originating within a seismic district. Cases of successive occurrences of destructive earthquakes from within a given seismic district are not rare. According to my new *Catalogue of the Destructive Earthquakes in Japan,*[*] there were, with the recent Shimabara (Hizen) earthquakes, altogether 12 instances of this nature, as mentioned below.

(i). Nikko earthquakes. Group of the Nikko seismic disturbances in 1683 began on June 11 with an earthquake at 6 A.M. followed by a strong one at 7 A.M.; there being 29 shocks on the next day between 5 A.M. and 7 P.M. and 8 during the night. On the 13th, some shocks. On the 20th, shocks at 8 A.M. and at noon. On the 17th, a shock at 5 A.M. was followed at 8 A.M. by a destructive earthquake which overthrew the sacred stone tombs of Iyeyasu and of Iyemitsu in the inner courts of the Toshogu and Daiyu-in temples, and also the 9-story tomb-stone of the high priest Tenkai; there being 89 after-shocks during the rest of the day. On the 18th, there were 7 shocks in the morning between 6 and 8 o'clocks, followed at 11 A.M. by a second destructive earthquake, which was stronger than that on the preceding day, and threw down the *ishigaki,* or dry-masonry retaining walls at the different places, the total number of the shocks during the day amounting to 196. On Oct. 20th of the same year, there took place a third destructive earthquake, which threw down anew the *ishigaki* then in the course of repair.

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[*] Shinsai Yobo Chosakwai Hokoku (Japanese Reports of the Imp. Earthq. Inv. Comm.), No. 88, C, (1919).

(ii). **Ogi (Sado) earthquakes, Dec. 9, 1802.** The 1st strong shock, which occurred at 8 A.M., caused landslips and some damage to the buildings at the town of Ogi (小木) situated on the S.W. coast of the island of Sado, the sea-water having temporarily been withdrawn from the beach to the distance of about 900 feet. At about 1 P.M. there took place a much stronger earthquake which was very destructive in Ogi, where fires immediately broke out from several quarters. The sea-water again receded to a distance of about 1500 feet. As the result of the shock, there was produced a sudden permanent elevation of the land to the maximum amount of about 8 feet, for the length of about 25 miles along the south and south-west coasts of the island.

(iii). **Iwashiro earthquakes.** On Dec. 13, 1821, the Oishi-gumi village district, in the valley of the Tadami-gawa (只見川), Onuma county, province of Iwashiro, was shaken by a strong earthquake which caused the destruction of 130 houses. On Jan. 26, 1822, the same district was shaken by a second earthquake which was stronger than that in the preceding year.

(iv). **Noto earthquakes.** Two strong earthquakes took place off the S.W. coast of the peninsula of Noto in Dec. 1892, respectively on the 9th, at 10.42 A.M. and on the 11th, at 1.30 A.M. The shock on the 9th produced cracks of ground and some damage to the buildings at the town of Takahama and the village of Hiuchidani, in the district of Hagui. In the shock on the 11th, two houses were destroyed, 1 person killed and 5 wounded at the village of Horimatsu in the same county. The origin of the 2nd earthquake was shifted about 8 km. to the south of that of the 1st.

(v). **Takai earthquakes.** The earthquake on Jan. 17th, 1897, at 5.36 A.M., shook strongly the district about the Chikma-gawa, 16 km. in the E.W. and also 16 km. in the N.S. direction, including the whole of the Kami-Takai county and the E. part of the Kami-Minuchi county. There were some damage to houses, crumbling of *ishigaki*, ground cracks, and sand ejection, at the villages of Watauchi, Kawada, Inouye, Hino, Toyosu, and Kobuse in the Kami-Takai county, and at Frusato, Naganuma, Yanagihara, Asahi, Daizu-shima, and Frumaki in the Kami-Minuchi county. On April 30th, at 4.02 P.M. there was a second strong earthquake which caused a similar amount of damage within an area, 20 × 8 km. in dimension, along and on the eastern bank of the Chikma-gawa, including nearly the whole of the Kami-Takai county and the S.W. portion of the Shimo-Takai county. It may be remarked that the origin of the second strong earthquake was situated under the Okuma-yama 10 km. to the N.N.E. of that of the first earthquake situated among the mountains about 4 km. to the S.E. of the town of Suzaka.

(vi). **Itoshima earthquakes.** The earthquake on Aug. 10, 1898, at 9.57 P.M., shook strongly the village of Maebara and the vicinity in the Itoshima district, province of Chikzen, Kyushu. On the 12th, at 8.36 A.M., there took place another strong earthquake, which was severer than the first, resulting in 3 persons wounded and 73 dwelling houses damaged. At the Hatae-mra the ground was cracked at several places on the occasion of the second earthquake.

(vii). **Hachinohe earthquakes.** Two strong earthquakes in Aug. 1901, respectively on the 9th, at 6.23 P.M. and on the 10th, at 3.34 A.M. were most severely felt in the Sannohe district, province of Mutsu, two houses having collapsed at the town of Hachinohe and also two at Negishi-mra.

The total seismic damage in the Aomori prefecture (Mutsu) was 18 persons killed or wounded, and 8 houses collapsed. There were also seismic damage in the Ninohe and Knohe districts (三戸郡九戸郡) of the Iwate prefecture, and at the Kosaka Mining Plant in the Akita prefecture.

The earthquake on Jan. 30, 1908, at 11.01 P.M., produced some damage to houses in the villages of Toyosaki, Gonohe and Konakano in the Sannohe district (三戸郡) and at the village of Shichinohe (七戸) in the Kami-Kita district.

(viii). **Earthquakes of Shinji (宍道), province of Izumo.** The strong earthquake of June 6, 1904, at 3. 40 A.M., was followed by a second and severer one on the same day, at 11. 51 A.M. Some damage was caused to houses and embankments at the villages of Otsuka (大塚), Mori (母里), and Uganosho (宇賀荘) in the district of Noki (能來郡).

(ix). **Earthquakes of Oshima (Izu), 1905.** Small shocks began from about May 28, and the 1st strong earthquake took place on June 5, at 1. 45 A.M., followed by the 2nd on the 7th, at 2.39 P.M.; the latter was chiefly responsible for the seismic damage produced in the island, there being, amongst the others, injuries to houses and *ishigaki* (stone retaining walls) at the villages of Motomra and Nomashi.

(x). **Kagoshima earthquakes, 1913.** The strong earthquake of June 29, at 5. 23 P.M., caused the falling down of cliff and the overthrow of sheds in the village of Nishi-Ichiki, Hioki district (日置郡西市來村湊町). Another strong shock, on the next day, at 4. 50 P.M., caused some damage to buildings in the city of Kagoshima, and at the villages of Nishi-Ichiki and Nagatani (永谷村) in the Hioki district.

(xi). **Omachi (Shinano) earthquakes, 1918.** On Nov. 11, there were two destructive earthquakes, at 2. 58 A.M. and 4. 03 P.M. respectively. The 1st proved destructive at the town of Omachi, and the neighbouring village districts of Matsuzaki (松崎), Jokoji (常光寺), Kirikbo (切久保), Reishoji (靈松寺). The 2nd shock was distinctly greater and was felt most strongly in the different districts of the village of Tokiwa, there being 6 persons wounded, 6 houses totally destroyed, and 2,852 houses partially damaged.

(xii). **Shimabara (Nagasaki) earthquakes, 1922.** On Dec. 8, 1922, there occurred in the Shimabara peninsula, Nagasaki prefecture, two severe earthquakes at 1^h 50^m A.M. and 11^h 02^m A.M. respectively; the 1st shock being nearly twice as great as the 2nd. The origin of the 1st shock was situated at the south base of the Unzen-dake volcano, at the distance of about 42 km. to the east slightly south of Nagasaki. The origin of the 2nd strong shock was shifted to the south-west base of the same volcano. The total amount of the casuality was 25 killed and 22 wounded.

4. Remarks on the successive occurrences of small destructive shocks. The cases of the successive seismic occurrences enumerated in § 3 relate all to the category of small destructive earthquakes. Even these did not originate from one and the same point, the centre of the 2nd shock being in each instance 1 to some 2 *ri* (4 to 10 km.) displaced from that of the 1st shock. Some of the earthquakes in which the origin transfer was evident were as follows:—

Noto earthquakes in Dec. 1892. The origin of the strong shock on the 9th was situated 4 km. off the coast of Togi and Takahama, province of Noto. The origin of the shock on the 11th was under the sea 8 km. further south.

Takai (*Shinano*) *earthquakes of* 1897. The strong earthquake on Jan. 17th had its centre among the mountains about 4 km. to the east of the town of Suzaka. The shock on April 30th originated under Mount Okuma about 10 km. further to the N.N.E.

Omachi (*Shinano*) *earthquakes on Nov.* 11, 1918. The strong earthquake at 3 A.M. originated at the vicinity of Jokoji and Kirikbo of the Yashiro village, about 8 km. to the S.E. of the town of Omachi. The 2nd and stronger shock at 4 P.M. had its origin along a zone extending 4 km. to the S.W. from the 1st centre.

The successive occurrences of the small destructive shocks are generally limited to two times, the 2nd being generally a little stronger than the 1st.

The time interval between the occurrences of the two shocks was 44 days in the case of the Aizu earthquakes of 1821–22, and 103 days in the case of the Takai (Shinano) earthquakes of 1897. In the 9 remaining cases, the interval in question was far shorter, and varied between 18 auf 61 hours, with the mean of 25 hours, as follows :—

			Time Interval.	
Nikko Eqkes.	on	June 17 and 18, 1683.	1 day	2 hour.
Noto	,,	Dec. 9 and 11, 1892.	1	15
Itoshima	,,	Aug. 10 and 12, 1898.	1	11
Hachinohe	,,	Aug. 9 and 10, 1901.		9
Shinji	,,	June 6, 1904.		8
Oshima	,,	June 5 and 7, 1905.	2	13
Kagoshima	,,	June 29 and 30, 1913.		23
Omachi	,,	Nov. 11, 1918.		13
Shimabara	,,	Dec. 8, 1922.		9
			Mean,.........	25 hour

5. Earthquake distribution. As will be seen from fig. 2, all the twelve twin earthquakes enumerated in § 3 belong to the inner, or concave, volcanic side of the Japan Arc, with one exception belonging to the Fuji volcanic chain. There were of course also local destructive shocks originating in the volcanic portions of Japan, which happened singly. (See § 8.) These were, however, comparatively few in number ; while there were several instances of the same geographical connection, in which local destructive shocks were repeated within a given seismic area at long time intervals. (See § 6.) On the other hand, the recent small destructive shocks originating in the non-volcanic portions (§ 7) were non-repetitive. It may be that the repetitive tendency of local destructive shocks forms a special feature of the volcanic portions of Japan.

6. Occurrences at long intervals of local destructive shocks from a given seismic district. In a number of cases the seismic disturbances of more or less destructive intensity took place at long intervals within a seismic district. The following are the cases of this category which occurred in Japan since the Kmamoto earthquake of 1889, divided into 6 groups, all belonging to the concave Japan Sea side of the Japan Arc :—

(1). Takai (Shinano) earthquakes of 1897.
(2). Muikamachi (Echigo) earthquakes of 1898 and 1904.
(3). Earthquakes in the eastern part of Shinano in 1908 and 1912, connected with the activity of the Asama-yama volcano.
(4). Teshio and Usu earthquakes, in 1910, connected with the activity of the Usu-san volcano.

(5). Satsuma earthquakes, in 1913, 1914, and 1915, connected with the volcanic activity of Sakura-jima.

(6). Akita earthquakes, in 1914.

(1). *Takai (Shinano) earthquakes of* 1897. (A). The earthquake in the Kami-takai district, province of Shinano, on Jan. 17th, at 5. 36. A.M. was felt strongly within an area about 16 km. in extension, along the Shinano-gawa, and caused some damage to buildings and *ishigaki*, overturning of stone lanterns and tomb-stones, cracks of ground, emission of sand and mud, etc. (B). The similarly severe earthquake on April 30th, at 4. 02 P.M., was felt strongly within an area 20 × 8 km. on the eastern side of the same river. The origin of the first shock was in the mountains about 4 km. to the east of the town of Suzaka, while that of the 2nd was situated 10 km. apart to the N.N.E. (§ 3.)

(2). *Muikamachi (Echigo) earthquakes.* (A). The earthquake on May 26, 1898, at 3. 00 A.M. was strongly felt at the town of Muikamachi, in the Minami-Uonuma district, where *dozo* walls were cracked and shaken down, and cultivated field were cracked. At Mizkami-mra (水上村), in the Tone district, province of Kotsuke, similar seismic damage was caused, several landslips having been produced among the mountains. The origin was situated in the vicinity of Muikamachi, at $\varphi=36°52'$N., $\lambda=138°55'$E., namely 147 km. to the N.30°W. of Tokyo. (B). The 2nd earthquake, on May 8, 1904, at 4.23 A.M., which was strongly felt at Isozawa-mra (五十澤村) in the Minami-Uonuma district, caused damage to the amount similar to that in 1898. The seismic origin was also in the vicinity of the town of Muikamachi, but displaced about 8 km. to the S.E. of that of the 1st shock, namely, to a point $\varphi=36°53'$N., $\lambda=138°48'$E., at 154 km. to the N.33°W. of Tokyo.

(3). *Earthquakes of Asama and vicinity.* (A). The Asama earthquake on May 26, 1908, at 9. 10 A.M., shook Asama and the Kita-Saku district at the south of the volcano. Cracks were produced at the rim of the crater, and rocks fell down from the old crater walls of Kiba-yama, Krofu-yama, and Maikake-yama. (B). The Asama earthquake on July 16, 1912., at 7. 46 A.M. was almost equal to the preceding in magnitude, intensity, and the production of damage. Cracks 3″ or 4″ wide were formed along the crater rim. Landslips took place at the base of the Kiba-yama opposite Yuno-taira, and from the inside of the Krofu-yama at a point called Tomi-no-kuchi, 0.5 km. to the W.W.N. of the latter. Trees were broken and the mountain path was obstructed by the large rock blocks precipitated at several places in the neighbourhood of the Hoinbo fall and the Nagasaka slope, while rock masses were broken from the old Oni-oshidashi lava flow on the northern base of Asama, with sound audible at the Wakasare cottage. At the Yuno-taira Seismological Observatory, the tromometer registered 48 sensible and 162 unfelt earthquakes in the course of the next 12 hours. (C). The Ueda earthquake on Aug. 17, 1912, at 11. 21 P.M. was felt strongly at and about the city of Ueda, where the ground was cracked to the width of 0.1 to 0.2 foot, porcelains were broken, and some *ishigaki* were damaged. The centre was situated about 6 km. to the N.N.W. of Ueda, or 26 km. to the west of Asama, at $\varphi=36^\circ 27'$N., $\lambda=138^\circ 15'$E. (D). The Ozasa earthquake on Feb. 22, 1916, at 6. 11 P.M. was strongly felt at the village of Ozasa and other places at the north base of Asama, producing some landslips and resulting in 7 dwelling houses overthrown, and 273 houses and other buildings partially damaged. The seismic origin was situated about 8 km. to the N.W. of the volcano, at $\varphi=36^\circ 28.'5$N., $\lambda=138^\circ 28.'8$E.

(4). *Teshio and Usu earthquakes,* 1910. (A). The Rumoe earthquake on June 16, 1910, at 9. 00 P.M., was very limited in area and felt strongly at the town of Rumoe, in the province of Teshio (Hokkaido), where, amongst the others, the Owada coal pit was damaged in consequence of the bursting of a new water fountain. (B). The Usu earthquake on July 25, 1910, at 3. 49 P.M. produced damage at the town of Apta situated at the west base of the Usu-san volcano, causing there partial destruction of 8 dwelling houses and of two brick, one stone, and four wooden ware-houses. The roads between Apta and Benbe, and between Apta and Tokotan were damaged for the aggregate length of 10 km. (C). Onishika earthquake on Sept. 8, 1910, at 11. 50 A.M. was felt strongly along the coast of the province of Teshio, for the length of some 100 km., producing some damage to buildings at the villages of Onishika and Tomasaki. The number of the after-shocks felt on the 8th and 9th was 42 at Rumoe and 39 at Onishika. The origin was situated under the sea about 20 km. off the coast.

(5). *Satsuma (Kyushu) earthquakes.* (A). Kagoshima earthquakes on June 29 and 30, 1913, at 5. 23 P.M., was felt strongly at Nishi-Ichiki in the Hioki district, causing some falling down of cliffs. (B). Kagoshima earthquake on the next day, at 4. 50 P.M., caused some damage in the city of Kagoshima, and at Nagatani (永谷村) and Nishi-Ichiki (西市來村), in the Hioki District. (C). The Sakura-jima earthquake on Jan. 12, 1914, at 6. 28 P.M. was much greater than the preceding two and proved most disastrous at the portions of Kagoshima near the sea, overthrowing 39 and partially damaging 1107 houses, and resulting in the casuality of 13 killed and 96 wounded, beside about 30 killed in the Kagoshima district exclusive of the city. The railway traffic was temporarily obstructed by the falling of huge rock blocks at seven places along the main Kyushu line, in the portion between the stations of Kagoshima and Shigetomi. The branch line between Kagoshima and Sendai was also slightly damaged between the stations of Take and Manju-ishi. The earthquake was followed about 1½ hours later on by a small *tsunami* (tidal wave) along the coast of Kagoshima. (D). Earthquake on July 14, 1915, at 9. 13 P.M. was strongly felt at Krino and Yoshimats, in the north-eastern part of the province of Satsuma, causing some damage to the roads and *ishigaki*. The seismic origin was situated, according to Dr. A. Imamura, at about 4 km. to the S.E. of Yoshimats.

(6). *Akita earthquakes of* 1914. (A). Senpok earthquake on March 15 was most violent at the villages of Kowakbi (强首), Omagari (大曲), etc. in the Senpok district, damage having been caused also in the city of Akita and the districts of Kawabe, M.-Akita, Yuri, Hiraga, and Okats. The total amount of casuality was 94 killed and 324 wounded, while 640 houses were totally overthrown and 575 partially damaged. (B). Hiraga earthquake on March 28, at 2. 49 A.M. was strongly felt at Numatate (沼館町) in the Hiraga district, where a few dwelling houses were overthrown. This town, situated 20 km. to the south of Omagari, had suffered only slightly in the previous shock.

7. Destructive earthquakes in the non-volcanic portions of Japan. Local destructive earthquakes which happened since 1889 in the non-volcanic portions of Japan are as follows :—

(1). Tokyo earthquake of June 20, 1894.
(2). Gei-yo, or Inland Sea, earthquake of June 2, 1905.
(3). Nagahama, or Torahime (Omi and Mino), earthquake of Aug. 14, 1909.
(4). Uma (宇摩郡) District (Iyo) earthquake of Aug. 2, 1916.
(5). Kobe earthquake of Nov. 26, 1916.
(6). Shizuoka Prefecture earthquake of May 18, 1917.
(7). Miyoshi (Hiroshima Prefecture) earthquake of Nov. 1, 1919.
(8). Kwanto earthquake of Dec. 8, 1921.
(9). Uraga Strait earthquake of April 26, 1922.

All these local destructive shocks happened singly, i.e., without successive repetitions from one and the same seismic district.

8. Single destructive earthquakes in the volcanic portions of Japan. The seven earthquakes described next are the cases of local destructive shocks, which happened since 1889, in the concave, or Japan Sea, side of the Japan Arc, or along the Fuji volcanic chain, all being, with the single exception of the Sabae (Echizen) earthquake, obviously connected with the volcanoes nearby.

(1). *Kmamoto earthquake* of July 28, 1889, at 11. 40 P.M. The shock was felt strongly in the city of Kmamoto and the district of Akita, the total amount of casuality being 20 persons killed and 74 wounded. The numbers of the houses totally and partially destroyed were each 200.

(2). *Miyake-jima earthquake* of April 16, 1890, at 9. 30 P.M. In Miyake-jima there were several landslips along the northern and western coasts of the island, crushing one house. In Nii-jima several tomb-stones were overturned, and some of the *dozo* overthrown.

(3). *Chiran (Kagoshima) earthquake* of Sept. 7, 1893, at 2. 25 A.M. This was a quite local shock, which was destructive at and about the village of Chiran, in the southern part of the Satsuma peninsula, overthrowing three houses, besides a remarkable landslip of a mountain slope about 0.8 *cho* in area at a place called Nagasato (永里).

(4.) *Sabae (Echizen) earthquake* of March 22, 1900, at 0.55 A.M. The shock was slightly destructive at the town of Sabae (鯖江) and the village of Yoshida (吉田) respectively in the Imadate and Nyu districts in the province of Echizen. There was one case of mountain slope landslip and the casuality consisted of 6 persons wounded, the numers of the totally and partially destroyed buildings being 3 and 10 respectively.

(5). *Mikra and Miyake islands earthquake* of Nov. 5, 1900, at 4. 42 P.M. At Miyake-jima, houses were damaged, *ishigaki* crumbled, rocks thrown down, and the roads were at places broken. At Mikra-jima, 120 landslips took place along the coast, burying the roads, and crushing three ware-houses. At Kozu-shima, 2 houses were destroyed and 3 partially destroyed, there being several cases of damage done to cliffs and tunnels.

(6). *Yake-dake earthquake* of Aug. 10, 1903, at 1. 40 P.M. The shock was felt within a narrow area in the Yoshiki district, province of Hida, not far from the Yake-dake volcano in the Japanese Alps. There were several cases of landslips. Some houses were damaged.

(7). *Aso earthquake* of Aug. 22, 1911, at 7. 48 A.M. The shock was felt in the Aso district, about the Aso-san volcano. At Choyo-mra (長陽村), there were damaged *ishigaki* and mountain landslips.

9. Successive occurrences of great earthquakes. I tabulate below the cases of the successive occurrences of great destructive earthquakes in Japan.

Shinano-gawa Valley.

[Bunsei, Tempo, and Koka Periods.]

(i) Sanjo (Echigo) Earthquake of Dec. 18, 1828.
Sado and Shonai Earthquake and *Tsunami* of Dec. 7, 1833.
Zenkoji (Nagano) Earthquake of May 8, 1847.

Central and S.W. Parts of Japan.

[Ansei Period.]

(ii) Iga, Ise, and Nara Earthquake of July 9, 1854, early morning.
Tokaido Eqke. and *Tsunami* of Dec. 23, 1854, at 9 A.M.
Nankaido „ „ „ 24, „ „ 5 P.M.
West Inland Sea Eqke. „ 26, „ „ 10 A.M.
Yedo (Tokyo) „ Nov. 11, 1855, „ 10 P.M.*

[Genrok and Hoei Periods.]

(iii) Yedo (Tokyo) and Odawara Eqke. and *Tsunami* of Dec. 31, 1703.
Yedo („) Earthquake of Oct. 21, 1706.*
Hoei Eqke. and *Tsunami* of Saikaido to Tokaido, Oct. 28, 1707.

[Keichô Period.]

(iv) Bepp and Uryu-jima Eqke. and *Tsunami* of Sept. I, 1596.
Fshimi (Kyoto) Eqke. of Sept. 4, 1596.
Kazusa, Awa, and Msashi Eqke. and *Tsunami* of Jan. 31, 1605.

[Meio Period.]

(v) Yamato Earthquake of June 19, 1494.*
Tokaido „ Sept. 20, 1498.

[Kanbun Period.]

(vi) Tosa Earthquake of Dec. 10, 1661.*
Kinai Provinces Eqke. of June 16, 1662.
Hyuga (Kyushu) „ Oct. 31, „
Kyoto „ Jan. 4, 1664.*
Shingu (Kii) „ Aug. 3, „ *
Kyoto „ June 25, 1665.*

Kyushu and Lyukyu.

(vii) Okinawa Earthquake of Aug. 29, 1909.
Hyuga „ Nov. 10, „

(viii) Hyuga Earthquake of Feb. 18, 1911.
Kikaiga-shima Eqke. of June 15, 1911.

Kurile Islands.

(ix) Urup Earthquake and *Tsunami* of Sept. 8, 1918.
Etrup „ „ Nov. 8, „

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* Those marked with asterisks were small or local destructive earthquakes.

Of the above examples, (i) comprises the great destructive earthquakes along the Shinano-gawa valley. The cases (ii) to (iv) all relate to the great seismic zone off the external, or Pacific, coast of Japan, whose activity was accompanied by the occurrence of large or local destructive shocks from the central portion of the Main Island or from the western portion of the Inland Sea. It is evident that the general stress accumulation along the whole length of an earthquake zone causes the occurrences of destructive shocks from its differents points. The successive distances between the origins of the three great earthquakes of Sanjo, Zenkoji, and Sado-Shonai, were each about 116 km., while the centres of the two extensive shocks of the Ansei period, namely, those of Tokaido and of Nankaido, on Dec. 23 and 24 respectively, were separated by a distance of 400 km. The groups vii, viii, and ix are also cases of the transference of the centre of great seismic activity along the external earthquake zone. In the Ansei group (ii) the time difference between the Tokaido earthquake and the Nankaido earthquake was 32 hours, and that between the latter and the West Inland Sea earthquake was 41 hours.

The Ansei (ii), the Genrok (iii), the Keicho (iv), and the Meio (v) groups indicate some mutual geographical resemblances among themselves. Thus, the Ansei (ii) and the Genrok (iii) groups each included two great earthquakes with *tsunami* of the Pacific origin and a Yedo (Tokyo) earthquake. Again, both of the Ansei (ii) and the Keicho (iv) groups included one great earthquake and *tsunami* of the Pacific origin and one destructive shock in the Kinai districts (Kyoto and vicinity), and another in the western part of the Inland Sea. The occurrence in the Meio group (v) of one great earthquake and *tsunami* of Pacific origin and a destructive shock in the Kinai districts is similar to the cases of the two groups (ii) and (iv).

Below I mention two cases, in which destructive shocks occurred successively, though not strictly from one and the same seismic zone.

Date of Eqke.	Eqke. Area.
June 2, 1905.	W. Part of Inland Sea.
,, 7, ,,	Vicinity of Oshima Island (Izu).
April 9, 1858.	Provinces of Etchu and Echizen.
,, 23, ,,	Town of Matsushiro (Shinano).

10. Repetition of the successive occurrences. The groups ii, iii, iv, and v as well as the groups vii and viii, mentioned in § 9, are cases of the repetition of the seismic occurrences along the external earthqukae zone. There were also instances of the repetitions after an interval of time of the successive occurrences from two given seismic districts, as follows :—

(1) Vicinity of the Chokai Volcano and the Tokyo Plain.

A.	July 10, 1804.	Great Kisagata Eqke.
	Dec. 7, 1812.	Eqke of Kanagawa and Hodogaya (Msashi.)
B.	June 20, 1894.	Severe Tokyo Eqke.
	Oct. 22, ,,	Great Shonai (Sakata) Eqke.

(2) Riku-U Provinces and the Pacific Region off the Sanrik Coast.

A.	June 15, 1896.	Eqke. and Great *Tsunami* of Sanrik Coast.
	Aug. 31, ,,	Great Rikchu-Uzen Eqke.
B.	March 15, 1914.	Senpok (Akita) Eqke.
	March 28, ,,	Hiraga (,,) Eqke.
	Nov. 1, 1915.	Eqke. and *Tsunami* along the Coast of Rikzen.

(3) Provinces of Shinano and Totomi.

A.	April 28, 1714.	Eqke. of Omachi-gumi.
	Aug. 22, 1718.	,, Totomi, Mikawa, and Shinano.
	Oct. 15, ,,	,, Iiyama (Shinano).
B.	May 18, 1917.	Eqke. of Totomi and Suruga.
	Nov. 11, 1918.	Destructive Eqke. of Omachi (Shinano).
	March 23 and 29, 1919.	Strong Eqke. of Iiyama and Nozawa (Shinano).

(4) Sakura-jina and Hakone Volcanoes and Urup Island.

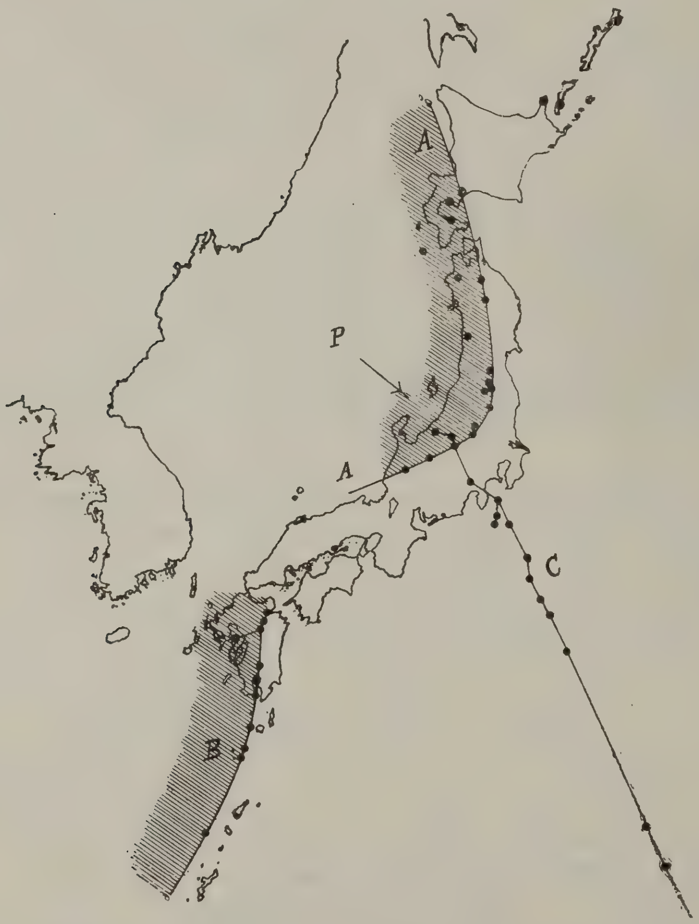
A.	Nov. 9, 1779.	Great Eruption of Sakura-jima.
	May, 1780.	Great Eqke. and *Tsunami* of Urup.
	Aug. 23, 1782.	Eqke. of Odawara.
	March 22, 1786.	Eqkes. and *Jinari* (sounds) at Hakone.
B.	Jan. 12, 1914.	Great Eruption of Sakura-jima.
	Jan. and Feb., 1916.	Eqkes. and *Jinari* (sounds) at Hakone.
	Sept. 8, 1918.	Great Eqke. and *Tsunami* at Urup.
	Nov. 8, ,,	,, ,, Urup and Etrup.

5 Volcanoes of Tarmai and Usu and the Teshio District.

A.	Feb. 8, 1874.	Eruption of Tarmai.
	Feb. 28, ,,	Eqke. of Rumoe (Teshio).
B.	June 16, 1910.	Eqke. of Rumoe (Teshio).
	July 24, ,,	Strong Eqke. of the Usu District.
	July 25, ,,	Eruption of the Usu Volcano.
	Sept. 8, ,,	Eqke. of Onishika (Teshio).

In (2), the *tsunami* of the Pacific origin off the Sanriku coast and the great earthquake in the Riku-U provinces were both repeated after a time interval of nearly 20 years. In (4), the great eruption of Sakura-jima, the earthquake and *jinari* (earth-sound) at the Hakone extinct volcano, and the great earthquake and *tsunami* at the Urup island were all repeated after an

Fig. 1. Map of Japan showing the Distribution of the Active and Dormant Volcanoes in Japan.



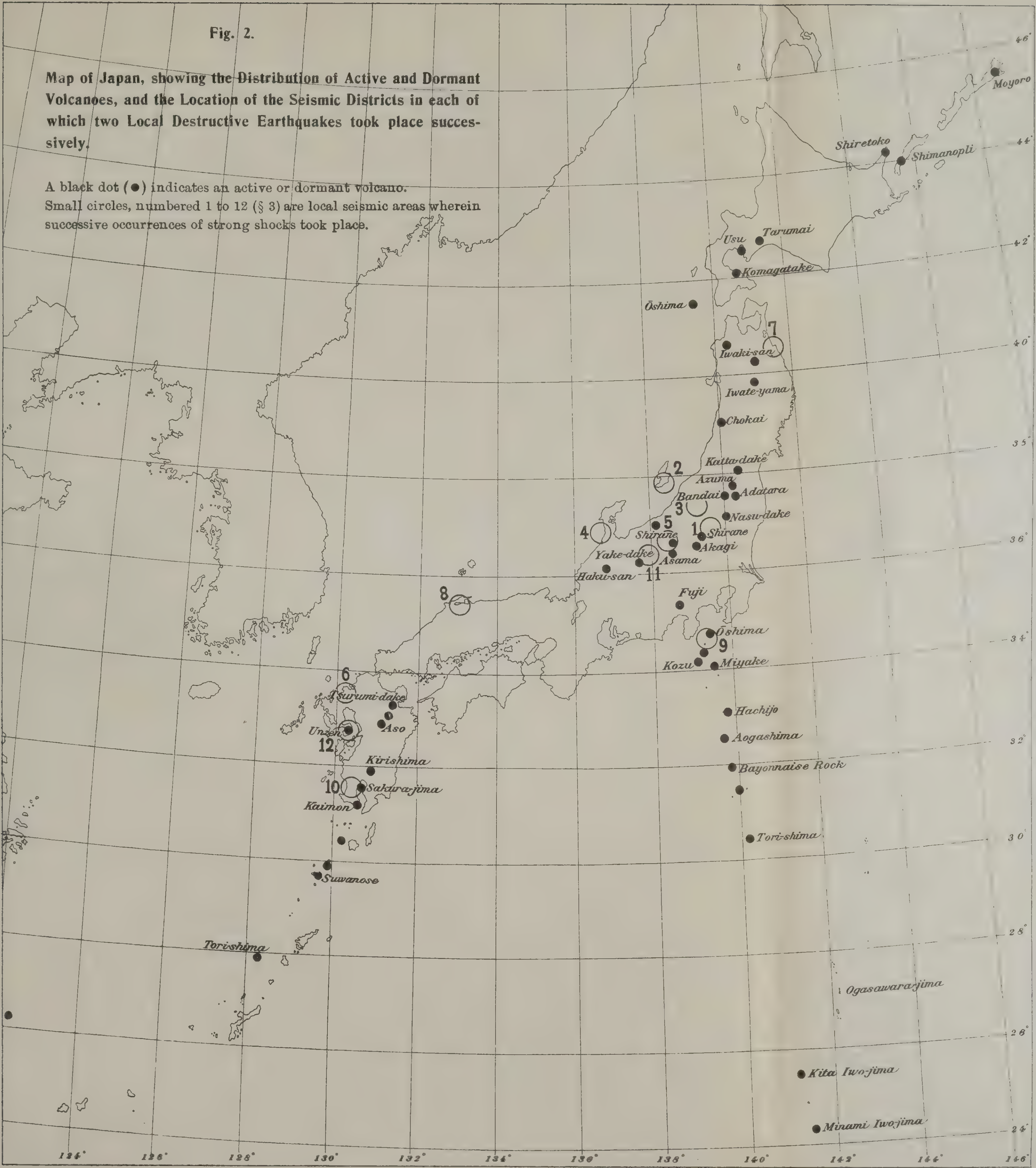
AA......Volcanic Region on the Japan Sea Side.
B........Kyushu and Lyukyu Volcanic Region.
C.........Fuji Volcanic Chain.
P.........Hoizontal Pressure acting from the concave side of Jaıan Arc.

Pl.

Fig. 2.

Map of Japan, showing the Distribution of Active and Dormant Volcanoes, and the Location of the Seismic Districts in each of which two Local Destructive Earthquakes took place successively.

A black dot (●) indicates an active or dormant volcano.
Small circles, numbered 1 to 12 (§ 3) are local seismic areas wherein successive occurrences of strong shocks took place.



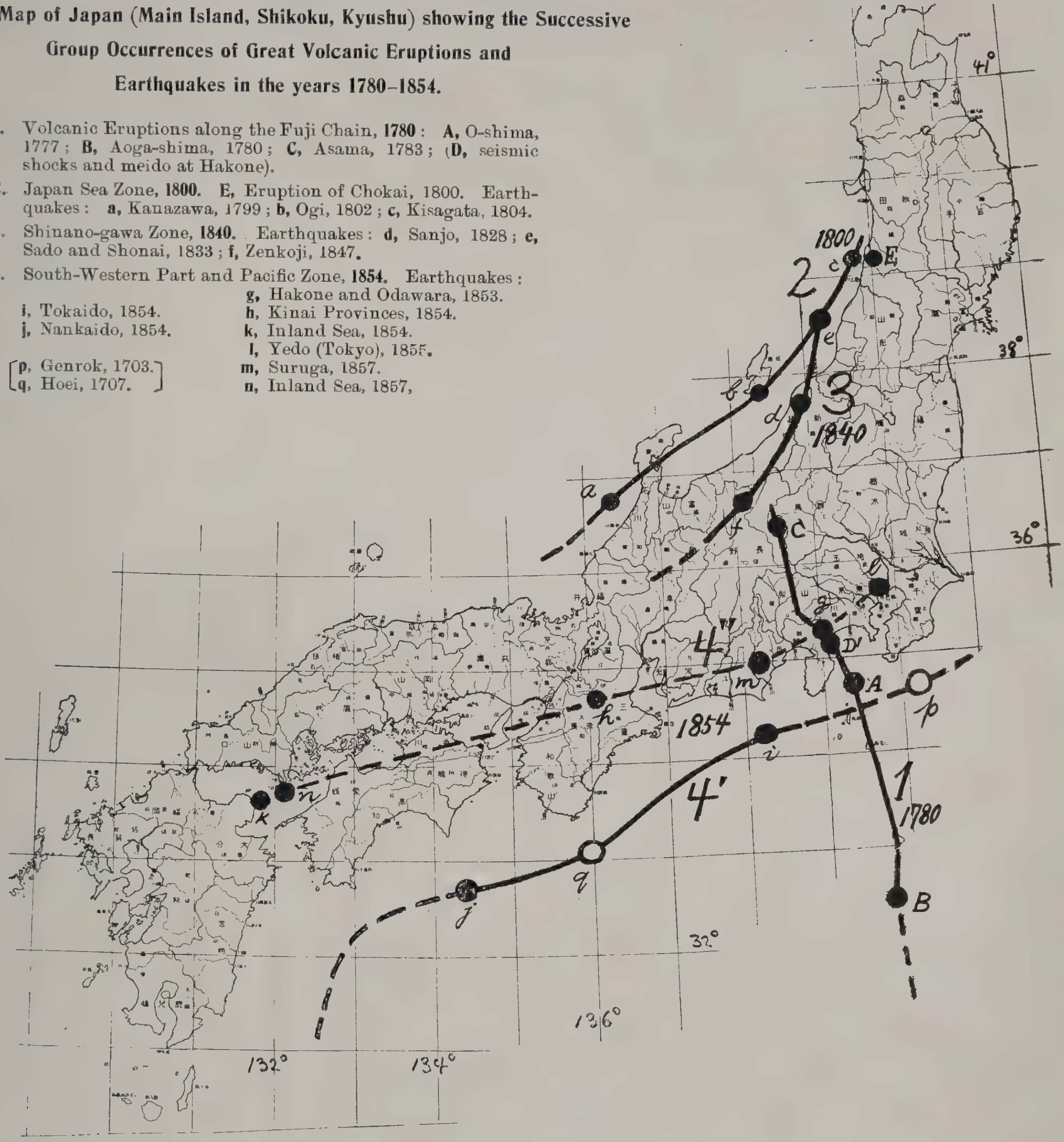
Pl. III.

Fig. 3.

Map of Japan (Main Island, Shikoku, Kyushu) showing the Successive Group Occurrences of Great Volcanic Eruptions and Earthquakes in the years 1780–1854.

1. Volcanic Eruptions along the Fuji Chain, **1780**: **A,** O-shima, 1777; **B,** Aoga-shima, 1780; **C,** Asama, 1783; (**D,** seismic shocks and meido at Hakone).
2. Japan Sea Zone, **1800.** **E,** Eruption of Chokai, 1800. Earthquakes: **a,** Kanazawa, 1799; **b,** Ogi, 1802; **c,** Kisagata, 1804.
3. Shinano-gawa Zone, **1840.** Earthquakes: **d,** Sanjo, 1828; **e,** Sado and Shonai, 1833; **f,** Zenkoji, 1847.
4. South-Western Part and Pacific Zone, **1854.** Earthquakes:

	g, Hakone and Odawara, 1853.
i, Tokaido, 1854.	**h,** Kinai Provinces, 1854.
j, Nankaido, 1854.	**k,** Inland Sea, 1854.
	l, Yedo (Tokyo), 1855.
[**p,** Genrok, 1703.]	**m,** Suruga, 1857.
[**q,** Hoei, 1707.]	**n,** Inland Sea, 1857,



interval of 130 years. In (3), there was a repetition after some 204 years of the destructive earthquakes at Omachi (Shinano), at Iiyama (Shinano), and in the provinces of Suruga and Totomi.

11. Successive occurrences of great eruptions and earthquakes in Japan, 1780-1854. (See Pl. III.) The great volcanic and seismic convulsions in Japan during the 80 years from 1777 to 1857, including the memorable eruptions of the Asama, the O-shima, and the Sakura-jima volcanoes, and the most violent earthquakes of Zenkoji, of Tokaido, of Nankaido, etc., indicate a clear series of successive transference of the telluric activity among the different volcanic chains and seismic zones, in four groups, at the mean epochs of about 1780 ; 1800 ; 1840 ; and 1854, as follows.

(I). Volcanic eruptions along the Fuji Chain, **1780**: O-shima, 1777 ; Aoga-shima, 1780 ; Asama, 1783.

(II). Japan Sea Zone, **1800.** Eruption of Chokai, 1800. Earthquakes : Kanazawa, 1799 ; Ogi, 1802 ; Kisagata, 1804.

(III). Shinano-gawa Zone, **1840.** Earthquakes : Sanjo, 1828 ; Sado and Shonai, 1833 ; Zenkoji, 1847.

(IV.) South-Western Part and Pacific Zone, **1854.** Earthquakes :

(A) Tokaido, 1854 ;
Nankaido, 1854.

(B) Hakone and Odawara, 1853 ;
Kinai provinces, 1854 ;
Inland Sea, 1854 and 1857 ;
Yedo (Tokyo), 1855 ;
Suruga, 1857.

(I), to begin with, the Fuji volcanic chain manifested its energy in the great eruption of O-shima (Izu) in 1777, followed by those of Aoga-shima in the south, and of Asama in the north, respectively in 1780 and 1783. (II), then the activity was transferred to the Japan Sea side, and the Chokai volcano in the north made a great eruption in 1801, resulting in the production of a new lava dome, called Kyowa-dake after the name of the period, which forms the present central highest peak. This had been preceded by the earthquake of 1799 in the south, off the coast of Kanazawa (province of Kaga), which was accompanied by *tsunami* (tidal waves). In 1802 there took place the destructive earthquake in the vicinity of Ogi in the province of Sado which caused a remarkable elevation along the south-west coast of the island for some 25 miles. The harbour of Ogi, which suffered a great inconvenience from the elevation of the terrain to the amount of 7 feet, had to be reconstructed at great cost to accommodate the anchorage for the ships. Two years later there took place another remarkable great earthquake, in 1804, at the base of the Chokai volcano, toward the north, resulting in the upheaval to the amount of 5 to 9 feet of the coast region for the extension of about 12 miles. Amongst the others, the lake of Kisagata, famous for its beautiful scenery, and termed the Matsushima of Dewa (old name for the provinces of Uzen and Ugo), was in consequence dried up, its numerous islets overgrown with pine trees since existing in the converted cultivated fields. (III), the seismic activity was then transferred to the Shinano-gawa valley zone, commencing with the Sanjo earthquake of 1828, followed by the submarine shock of 1833 in the north. This latter earthquake, whose origin was at the intersection of the above-mentioned earthquake zone with that off the Japan Sea coast, also caused *tsunami* (tidal waves) along the shores of Sado and of the provinces of Uzen and Echigo. The great earthquake of Zenkoji (Nagano) in 1847 finished the seismic disturbance in the period under consideration. (IV), then came the Ansei earthquake group, the two greatest shocks on Dec. 23 and 24, 1854, taking place off the Pacific coasts of Tokaido and Nankaido respectively. In the same epoch, 1853 to 1857, the destructive earthquakes took place along a line connecting the depressed areas of the Inland Sea, the Osaka bay, the bay of Ise, and the Tokyo bay, namely, at Odawara and Hakone ; in the province of Iga, Ise, and the vicinity of Nara ; in the western parts of the Inland Sea ; at Yedo (Tokyo) ; and in the western part of Suruga. Finally, the earthquake of 1858 at the boundary of Echizen, Etchu and Hida, corresponding to the s.w. prolongation of the Shinano-gawa zone, finished the seismic disturbance.

The occurrence of the different seismic and volcanic disturbances above-mentioned may be summarized as follows :—The activity was initiated, (I), by the excessively powerful eruptions along the Fuji volcanic chain, which may be regarded as a great fissure formed normally to the volcanic district composing the concave, or compression, side of the Japan Arc. This may be assumed as an indication of the stress accumulation, and probably the effect of a general elevation in the earth's crust along the whole extension of the latter, and it was natural that, (II), the next manifestation of the telluric activity should be located on the Japan Sea side, including an eruption of the Chokai volcano. The special feature of the earthquakes (and the eruption) of this group is that they were accompanied by *tsunami* (tidal waves), and by remarkable elevation of the coast regions, both of the island of Sado and of Japan Sea side of the Main Island. Then, (III), the adjacent Shinano-gawa zone was put in activity which forms an intermediate link between the Japan Sea and the Pacific coasts. The south western portion of Japan was finally brought into an unusual seismic activity. In short, the great convulsions in the period

1780–1854 may be considered as the manifestation of the results of the underground stress accumulation in the central portions of the Japan Arc and about the Fuji volcanic chain.

12. Conclusion. It is evident that the successive occurrences of great and local destructive earthquakes in and about the Japan Arc is by no means rare. Even small destructive shocks originating in a local seismic district do not have exactly one and the same centre. In the occurrences along an active seismic zone of great destructive earthquakes at close time intervals, like those in the Ansei period, the centre of disturbance would be displaced each time several score to several hundred km. apart. As a destructive earthquake is equivalent to the removal of a great stress accumulation in the earth's crust and as it does not originate beyond a cetain depth below the surface, seismic disturbances of extensive magnitude ought not to recur at one and the same locality, at least for a considerable time length. As a matter of fact there was in the historical times of Japan no case of repetition of the occurrence of great destructive earthquakes from one and the same centre.

As the Japan Arc forms a great seismic and volcanic region, or system, all the old, recent, and future earthquakes and volcanic eruptions in different parts of the empire are to be regarded as being more or less mutually related. This principle forms the basis of the researches concerning the earthquake zones and the future seismic disturbances in Japan.

On the Focal Depth of the Earthquakes originating in the Kwanto Provinces.

By

F. OMORI.

The distance ($= x$ km.) of the seismic centre from a given observing place, calculated from the duration ($= y$ sec.) of the preliminary tremor of the earthquake motion, by the formula $x_{\text{km}} = 7.42\, y_{\text{sec.}}$* denotes the approximate length of the path from the actual focus, and not the surface radial distance from the epicentre. Hence the arcs drawn on a map with three different places, s_1, s_2 and s_3, mutually not much distant, as centres, with radii corresponding to the distances calculated from the above formula, generally form a circular triangle, whose centre, *m*, or the point near which the bisectors of the three angles mutually pass may be assumed to indicate the approximate position of the epicentre, C, should the three stations form a triangle surrounding the latter, (fig. 1). In case the circular triangle lies outside of the triangle $s_1\, s_2\, s_3$, as in fig. 2, the position of the epicentre C may be assumed to be not far from the point near which the bisectors of the two external angles meet that of the remaining angle. With the epicentral distance (r) of a given place

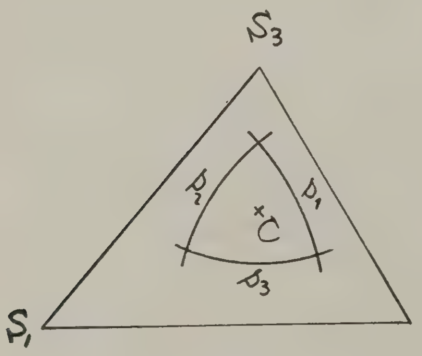


Fig. 1.

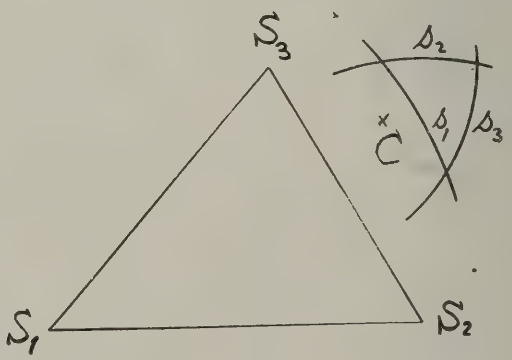


Fig. 2.

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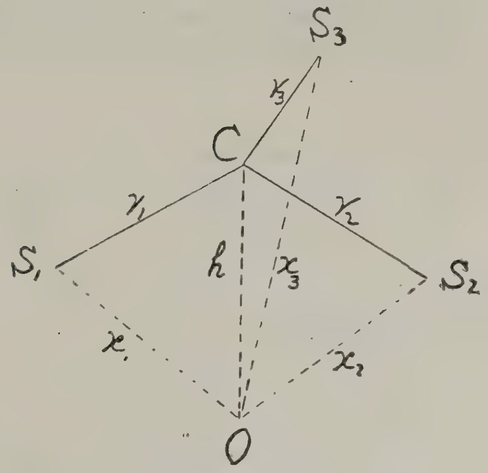
* The Bulletin of the Imp. Earthq. Inv. Comm., IX. (1918), p. 33.

Fig. 3.

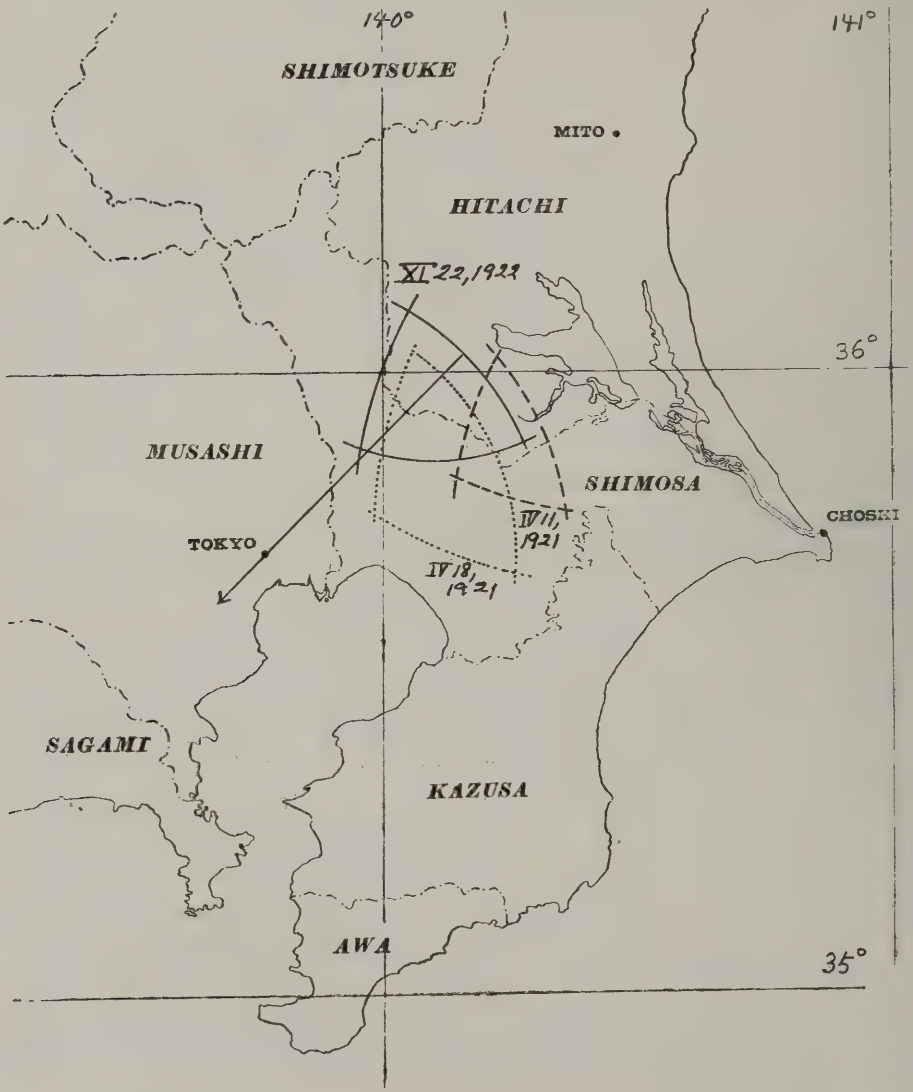


thus found and the distance x respectively as the horizontal side and the hypothenuse of a right-angled triangle, the vertical side gives the approximate depth (h) of the focus ; the neccessary conditions for the determination of the position of the epicentre being as follows (fig. 3) :—

$$h^2 = x_1^2 - r_1^2 = x_2^2 - r_2^2 = x_3^2 - r_3^2$$

where *x's* and *r's* are the radial distances of the three stations from the seismic focus and the epicentre respectively. (See fig. 4.) Applying this method to the recent seismographical observations at the Seismological Institute ($\varphi = 35° 42' 35''$ N., $\lambda = 139° 45' 58''$ E.), and the meteorological observatories of Mito ($\varphi = 36° 22' 44''$.E., $\lambda = 140° 28' 18''$ E.), and Choshi ($\varphi = 35° 44' 11''$ N., $\lambda = 140° 51' 38''$ E.), the 21 earthquakes felt in Tokyo in 1919–1922, of strong, moderate, or slight intensity, and with the origin situated in the Kwanto provinces of Shimosa, Hitachi, Awa, Kazusa, Sagami, and Musashi, give the focal depth varying between 16 and 49 km. with the average value of **33** km. (See the annexed table.) This may be regarded as the approximate mean depth at which the earthquakes in the neighbourhood of the lake of Kasumiga-ura originate, the epicentral distance from Tokyo varying between 31 and 112 km.

Fig. 4. Map showing the Positions of some of the Seismic Centres determined from the Observations at Tokyo, Mito and Choshi.



The date of each earthquake is affixed to the arcual triangle drawn about the three places of observation as centres. The arrow indicates the direction of the initial displacement of the eqke. of Nov. 22, 1922. observed in Tokyo.

Focal Depth of the Kwanto Earthquakes.

Date.	Time of Occurrence in Tokyo.	Intensity in Tokyo.	Duration of Prel. Tremor.			Position of Earthquake Origin.	Focal Depth.
			Tokyo.	Cho-shi.	Mito.		
1918.							
	h m s		sec.	sec.	sec.		km.
IV 19*	8 20 46 P.M.	Moderate.	5.2	15.8	12.0	N.E. part of Musashi.	16.0
X 4	11 56 32 A.M.	„	8.5	11.2	12.0	N. part of Kazusa.	36.0
1919.							
I 20*	0 26 07 P.M.	Moderate.	7.6	8.6	9.6	Boundary of Hitachi and Shimosa, to the S. of Kasumiga-ura.	31.0
VI 1	8 34 27 A.M.	„	10.0	9.6	7.0	Kasumiga-ura.	37.0
VI 9	8 14 54 A.M.	Slight,	9.7	5.5	8.3	To the S.E. of Kasumiga-ura.	21.0
VI 12	10 15 26 P.M.	„	9.9	9.9	8.2	To the S.W. of „	43.0
VIII 15	11 06 42 A.M.	„	8.5	10.4	11.8	Central part of Shimosa.	49.0
1920.							
V 8	0 02 21 P.M.	Slight.	7.6	11.2	7.9	Vicinity of the town of Shimotsuma.	30.0
IX 5	5 44 56 A.M.	„	15.4	4.7	15.0	Submarine, to the E. of Choshi.	20.0
1921.							
IV 11	9 02 44 P.M.	Slight.	7.3	8.9	9.1	To the S.W. of Kasumiga-ura	29.0
IV 18	2 33 57 P.M.	„	6.0	10.8,	10.8	S.W. part of Shimosa.	33.0
X 2	11 58 20 P.M.	Moderate.	9.0	7.8	10.7	N.E. part of Shimosa.	38.0
XII 8	9 31 41 P.M.	Strong.	8.8	9.4	8.0	To the S.W. of Kasumiga-ura, near the boundary of Hitachi and Shimosa.	29.
XII 26	10 15 09 P.M.	Slight.	12.4	4.7	11.0	To the S.E. of Kasumiga-ura.	32.
XII 29*	11 06 50 P.M.	„	5.5	14.6	11.0	N.E. part of Musashi.	22.
1922.							
IV 26	10 11 41 A.M.	Semidestructive.	11.1			In the Uraga Strait.	48
V 9	0 28 57 P.M.	Strong.	7.8	10.6	9.0	Boundary of Hitachi and Shimosa, to the S.W. of Mount Tsukuba.	32
VIII 25*	4 45 35 A.M.	Moderate.	8.2		(Tsukba:5.6)	*Do.*	37
XI 22	0 49 06 P.M.	Slight.	6.8	11.3	(Tsukba:5.3)	S.W. part of Hitachi.	29
I 4	3 32 59 P.M.	Slight.	7.1	10.4	9.0	N. part of Shimosa.	32
I 14	2 04 06 P.M.	Unfelt.	12.6	5.8	11.0	„	40

(*) Accompanied, in Tokyo, by a loud sound.

Earthquake Zones in and around the Pacific.*

By

F. OMORI.

Introduction. An earthquake is caused when the stress in a given portion of the earth's crust reaches a limit and gives rise to the production of a sudden underground dislocation, crack, compression, elevation, depression, etc., a large seismic disturbance being equivalent to the removal of an extensive geophysical strees. Naturally there are non-seismic and seismic areas, and, broadly speaking, the regions about the Arctic, namely, the northern parts of Russia, Siberia, and Canada are subject to least seismic visitations, while the margin of the Pacific ocean forms the most active earthquake zone of the earth.

Pacific coasts. In South America there stands the great mountain range of the Andes right along the Pacific coast, while the sea off the latter reaches the depth of over 7000 metres. The steepness of the surface gradient, which must favour the occurrence of earthquakes, exists also along the Pacific coasts of North America, Aleutian islands, and of the Japanese islands. The two latter series of islands furnish, together with Sumatra-Java and the Himalayas, great well-defined peripheral arcs, with cancavity turned toward thec ontinent of Asia, the steeper, or deeper, region being always on the convex side. The arcual form in question may be supposed to be the result of a horizontal pressure applied from the inner, or concave, side. The genesis of this marginal action may be attributable to the possible sinking down of the great continental mass, which perhaps has already passed the limit of elevation and has entered upon the stage of settlement. Thus, in the arcs under consideration, the concave and the convex sides are to be regarded as areas of compression and of tension respectively. The convex, or tension, side forms in each case the principal seismic region; while the concave, or compression, side is essentially the volcanic region. This fact is well indicated in the Aleutian, Japan, and Sumatra-Java arcs, which abound in volcanoes and which are frequently shaken by great submarine earthquakes originating off the convex side. The distribution of volcanoes and seismic centres in Italy furnishes another example of the illustration of the same principle.

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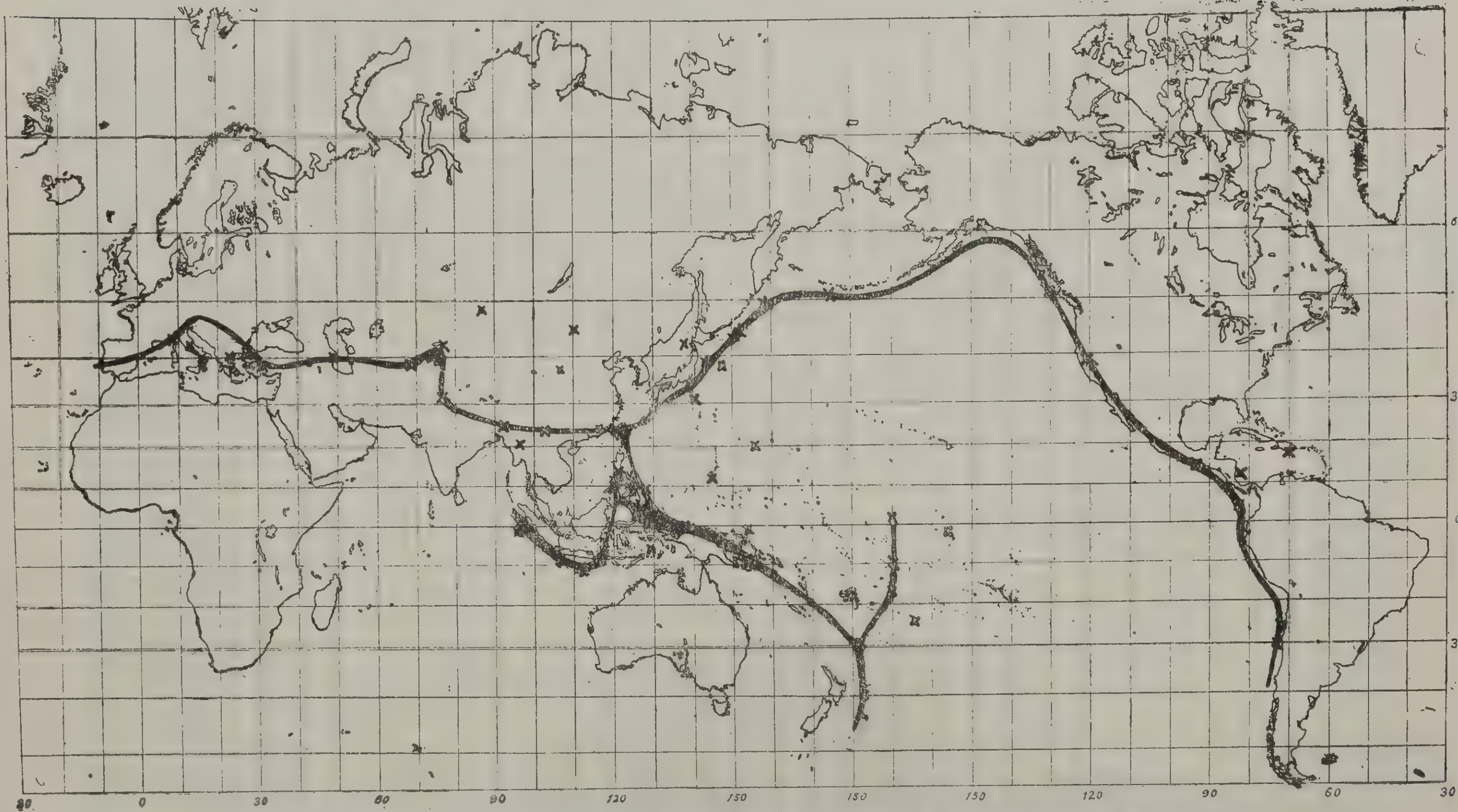
* Reproduced from the Proceedings of the First Pan-Pacific Scientific Conference (1920.)

Volcanic and seismic districts. The Japan and other arc systems as well as the whole border of the Pacific may be regarded each as forming a volcanic chain or an earthquake district. Hence it is natural that, in an epoch of activity, great volcanic or seismic disturbances should happen in succession from different parts of such an arc as the result of accumulation of the underground stress affecting the whole system. Thus, in Japan the volcanoes of Oshima, Sakura-jima, and Asama made tremendous outbursts in the years 1777 ; 1779 ; and 1783 respectively. After an interval of about 130 years, the same three volcanoes made again great convulsions between the years 1909 and 1914, although the Sakura-jima is in Kyushu and widely separated from the two other mountains belonging to the Fuji volcanic zone. Between these two remarkable periods of the volcanic activity, the epoch of 1853–1859 was one of an extraordinary seismic activity, there being no less than twelve destructive earthquakes in different parts of Japan; amongst others, the two great shocks off the southern and south-western coasts of Japan on Dec. 23 and 24, 1854, produced *tsunami*, or tidal waves, which crossed the Pacific and were recorded on the tide gauges at San Francisco, San Diego and Astoria.

Pacific earthquake-zone. Great destructive earthquakes do not take place at any district at random, but originate along weak lines in the earth's crust which may be termed *earthquake zones*. From the map, which indicates the distribution of the origins of the more prominent among the extensive non-volcanic earthquakes since 1897, it will be observed that the flat suboceanic regions of the north and south-east Pacific is seismically very quiet, while the most active earthquake zone runs off or along the coast of the South and North America and of the Aleutian and Japan arcs. In the south-western part of the Pacific, remarkably deep local basins are found off the arc formed by the islands of New Guinea, New Caledonia, and New Zealand, it being exactly there that great earthquakes originate. Taking the latter arc as denoting the real south-west boundary of the great ocean, we may say that the margin of the Pacific forms the great earthquake zone in the world. To the west it is prolonged to the outer base of the Himalayas, and through Turkestan and Caucasus, to the northern coast of the Mediterranean. Large Pacific earthquakes are often accompanied by destructive *tsunami*.

Earthquake occurrence. Great earthquakes, which remove over-strained conditions in the earth' crust and which originate near the surface, occur at different places of an eartnquake zone at different times, not repeating from one and the same point. Thus, the Japan earthquake on Dec. 23, 1854 took place off the coast of Tokaido, while the equally extensive shock on the next day originated from the same earthquake zone, 200 miles to the west, off the coast

Map showing the Position of the Pacific Earthquake Zone and its Himalaya-Mediterranean Continuation.



The small crosses (×) indicate the positions of Origins of the prominent large earthquakes in recent years.

of Nankaido. Again the series of the great earthquakes, (1) off the north west coast of Alaska in 1899, (2) the Mexico and Central America earthquakes in 1900 and 1902, and (3) the Panama, Columbia, and Equador earthquake on Feb. 1, 1906, had to be regarded, not as independent and unconnected events, but as the results of the stress accumulation at different parts of the seismic zone along the Pacific coast of North and South America. Thus the turn was to come next to some place between (1) on the north and (2) and (3) on the south, along the coast of the United States. This expectation was fulfilled in the San Francisco disaster on April 18, 1906. My further prediction that the next great shock would probably occur at the southern prolongation of the active part of the zone in question, to the south of the equator, was verified in the Valparaiso earthquake on Aug. 16, 1906. It is remarkable that this was preceded by only half an hour by another great submarine disturbance to the south of the Aleutian arc. The almost simultaneous occurrences of two great shocks from the two extremities of the American branch of the Pacific seismic zone, at a mutual distance of some 10,000 miles, prove the existence of the zone itself. There are other cases in which great seismic disturbances occurred within a few years from opposite extremities of an earthquake zone. Thus, the 1897 Assam-Bengal and the 1905 Kangra (Punjab) earthquakes occurred nearly 1,000 miles apart at the external foot of the Himalayan arc respectively near the eastern and the western ends. Again, the Messina earthquake of 1908 and the Avezzano earthquake of 1915 originated about 400 miles apart respectively near the south and the north ends of the central and south Italy earthquake zone. The occurrence of the Swatow earthquake on Feb. 13, 1918 is interesting, as the Himalaya-Mediterranean seismic zone had been assumed to be continuous with America-Japan zone through the southern maritime provinces of China, although these had no record of previous destructive shocks.

Earthquake prediction. Studies on the time and space distribution of earthquakes and volcanic eruptions have thrown some light on the problem of the prediction of these events. Especially considerations respecting seismic zones give as in some favourable cases hints as to the probable locality of occurrence of future great tectonic earthquakes. The popular idea of repetition of destructive shocks successively at one and the same point is a great fallacy ; a place seismically most dangerous being such as belongs to a powerful seismic zone, but has not yet, at least in the historical times, been shaken by a destructive earthquake originating right under it or very close to it. An important task for the practical seismologist in an earthquake country is to make a through study of the location and history of the seismic zones, to infer the intensity of motion in future earthquakes likely to affect a given district, and suggest proper methods to be followed in architectural and civil engineering structures. The mitigation of the destructive consequences of earthquakes can be very materially effected by the adoption of even a slight amount of earthquake-proof measures. It is no rare thing in Japan that some wooden cottages remain standing even at the epicentral districts of tremendous earthquakes, as was the case at the Neo-Valley in the Mino-Owari earthquake of 1891.

Relation between earthquake and volcano. Volcanoes and the centres of large tectonic earthquakes show distinct space distributions. A volcano, whether active, dormant, or dead, may often become the centre of numerous volcanic earthquakes. These are generally local and weak, and, even when strongest, belong to the category of what may be termed a small destructive shock, namely, one causing such damage as the fracture of brick chimneys, collapse of stone houses and badly built brick houses, loosening and breaking of cast iron waterwork pipes, etc. A volcanic district may be assumed to be free from the visitation of a great destructive earthquake, namely, one whose area is extensive and whose intensity of motion is sufficient to destroy properly constructed wooden or iron buildings. Houses built of very bad building materials, whose tensile strength is practically zero, have no earthquake-proof capacity, and will be wholly crushed down or scattered about at once simultaneously with the commencement of the strong motion phase of the earthquake. These may, of course, be destroyed even by volcanic earthquakes of the severer intensity.

Hawaiian islands. The Hawaiian islands are not likely to be visited by such great seismic convulsions as take place along the margins of the Pacific. The stronger local shocks will, however, prove destructive to badly built structures of stone or brick. Consequently it is absolutely necessary that houses in the Hawaiian islands should be built with proper earthquake-proof precautions.

Seismographical Observations in Tokyo of the Earthquakes with Sound.

By

F. OMORI,

Member of the Imperial Earthquake Investigation Committee.

With Plates IV–XIX.

1. Introduction. The majority of the earthquakes felt in Tokyo are not accompanied by sounds; those accompanied by sounds occur rarely, with the average yearly frequency of only about 4, roughly constituting 15% of the sensible shocks in Tokyo.

The earthquake sounds which are perceived in Tokyo are of two types: (A), detonative noise (*don, dodon, ton,* like that caused by the falling of a heavy weight on the ground or like the booming of a distant gun firing; (B), feeble rushing noise like that of wind blowing at a distance. Tables I and II embody the results of the observations on the earthquake sounds which I have made in Tokyo, during the course of the 16 years, 1907–1922.

In the present note the sound phenomena are considered with respect to the position of origin and the cause of the earthquakes, based on the tromometer measurement of the seismic motion.

2. Sound and earthquake motion. The A-type sound is perceived in general only at the commencement of the earthquake motion and lasts 0.5 sec. or so, being usually composed of a single report and very rarely of a series of a few reports. The B-type sound is likewise perceived at the commencement of the preliminary tremor. It is, however, likely that the sounds of both types often exist also at the commencement of the maximum motion phase*, but become unperceptible on account of the prevalence of the noises then caused by the shaking of the houses and furnitures.

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* For an illustrative case, see my paper, "Observation of Local Earthquakes on Mount Tsukuba, in 1905," Publication of the Imp. Earthquake Investigation Committee, No. **22**, A, (1908).

It is likely that the sound of either type which accompanies a great destructive earthquake is astoundingly loud. But it by no means follows that all the strong earthquakes are accompanied by sounds. Thus, of the three strongest earthquakes felt in Tokyo since the Yedo (Tokyo) catastrophe of 1855, namely, those of June 20, 1894, at 2. 04 P.M.; Dec. 8, 1921, at 9. 31 P.M.; and April 26, 1922, at 10. 11 A.M.; the first two were accompanied by no distinct sound, while the third was initiated by some low indefinite sound.

3. Seismograms. A careful examination of the tromometer registers shows that the horizontal motion has no special feature distinguishing the earthquakes with sounds of either type from those not accompanied by sounds; the commencement of the horizontal preliminary tremor, whose duration is well defined, being generally composed of extremely minute vibrations. (See figs. 25, 26, 28, 36 and 37.) The *vertical component* of the earthquake motion with the A-type sound is, however, quite characteristic and begins with a sudden prominent displacement, which often forms the absolute maximum vertical amplitude of the whole earthquake, (fig. 1). In these cases, therefore, the preliminary stage of the vertical motion corresponding to the "preliminary tremor" of the horizontal component, is not relatively small at all. Illustrative seismograms are reproduced in Pls. V, VI, etc.

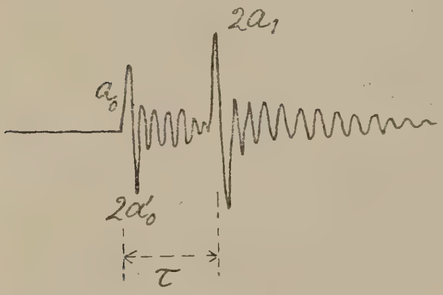


Fig. 1. Diagrammatic representation of the Vertical Earthquake Motion with the A-type sound.

a_0 ......Initial vertical displacement (single amplitude).
$2a'_0$ ....Counter displacement (double amplitude.)
$2a_1$ ......Maximum motion (double amplitude) in the succeeding phase (corresponding to the principal portion in the horizontal component).
τ......." Preliminary Tremor."

The initial displacement a_0, which may be directed downwards or upwards, is considerably greater than the movements at the commencement of the horizontal component. The vertical component of the earthquake with the B-type sound indicates no peculiarity of this kind.

In the subsequent description of the seismograms, the following notations are used :—

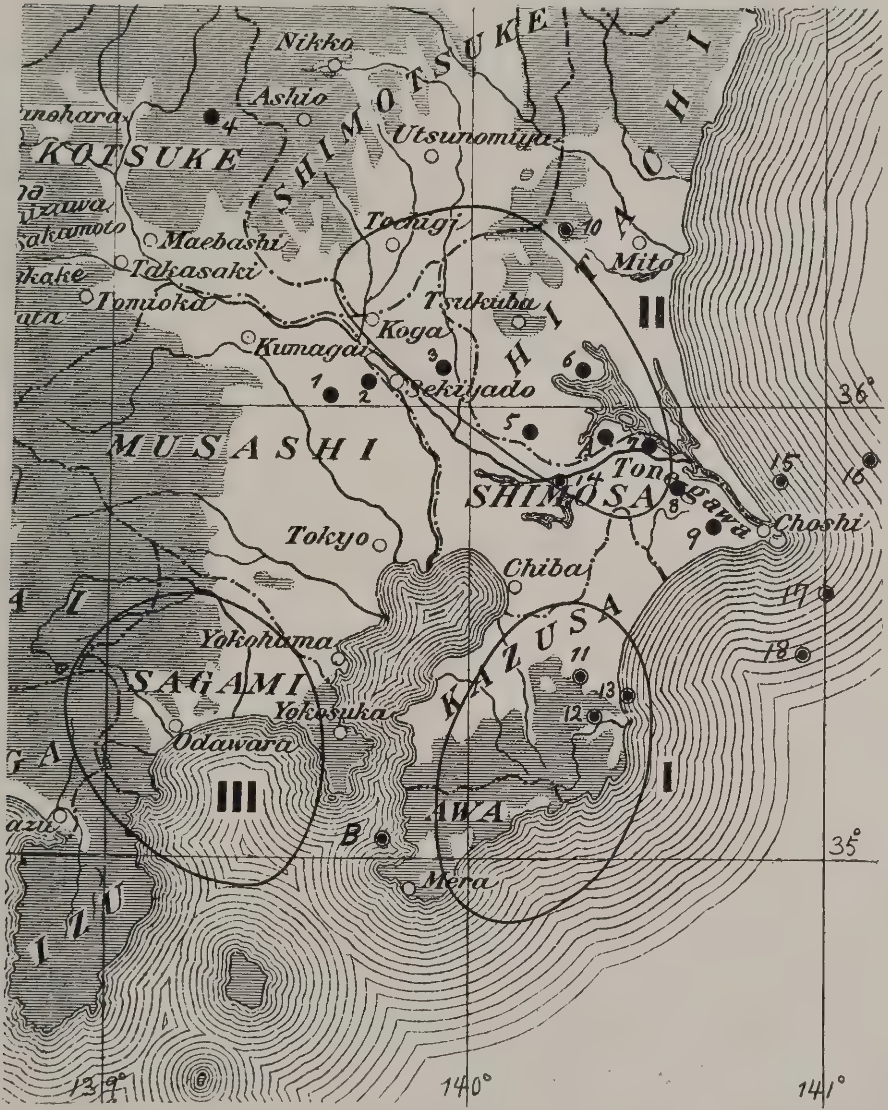
Pl. IV.

Fig. 2.

Map of the Kwanto Provinces, showing the Location of the Centres of the Sound Earthquakes perceived in Tokyo, and of the Earthquakes with the well developed Vertical Preliminary Tremor observed at Choshi.

The three elliptical or oval areas, I, II, and III, mark the regions where the recent earthquakes sensible in Tokyo mostly took place.

● indicates a case of initial upward motion.
◉ ,, ,, ,, downward motion.



Tokyo Observation.

Earthquakes with A-type Sound.

(1). IV 19, 1918.
(2). XII 29, 1921.
(3). VIII 25, 1922.
(4). VII 3, 1920.
(10). VIII 21, 1916.
(11). X 4, 1918.
(14). I 24, 1919.
(12). V 19, 1915.
(13). V 19, 1915.
(A). XII 8, 1911.
(B). IV 26, 1912.

Choshi Observation.

(5). I 4, 1922.
(6). VI 1, 1919.
(7). VI 9, 1919.
(8). I 4, 1922.
(9). XII 26, 1921.
(15). XI 9, 1922.
(16). VII 10, 1919.
(17). XII 2, 1921.
(18). IX 5, 1920.

The *shaded* parts are of Tertiary and other rocky formations, while the *unshaded* (white) parts are the alluvial and diluvial plains.

$2a$ = Range of motion (double amplitude) generally.
T = Complete vibration period.

a_0 = 1st vertical displacement (single amplitude).
$2a'_0$ = Counter displacement (double amplitude).
$2a_1$ = Maximum motion (double amplitude) in the subsequent stage, or the principal portion.

4. Older observations. The following table gives the list of the earthquake sounds which I have observed in Tokyo during the course of the 6 years, 1900 to 1906.

Earthquake Sounds perceived in Tokyo, 1900–1906.

Date.	Time of Occurrence.				Sound.
	h	m	s		
Aug. 27, 1900.	2	59	52	P.M.	Loud sound, mistaken by many for a gun booming.
June. 23, 1902.	7	42	42	A.M.	Loud rumbling sound, mistaken by many for distant thunder.
May. 6, 1903.	8	51	54	A.M.	Sound like distant thunder.
July. 23, 1902.	11	52	30	P.M.	Sound like that caused by a heavy weight falling on the ground.
Feb. 12, 1900.	7	37	43	A.M.	Rushing sound.
June. 24, 1902.	9	06	32	P.M.	„
Nov. 10, 1903.	6	50	54	P.M.	„
Feb. 26, 1904.	5	50	12	P.M.	„
Aug. 4, 1904.	9	49	17	P.M.	„
April. 6, 1905.	9	29	43	P.M.	„
Feb. 24, 1906.	9	14	42	A.M.	Sound like that caused by a wagon passing over a wooden bridge.

Table I. Tokyo Observation of the

Date.	Time of Occurrence.	Intensity.*	Duration of Prel. Tremor.	Duration of Sensible Motion.	Total Duration.	Max. 2a.
	h m s		sec.	sec.	min.	mm.
Feb. 23, 1907.	3 02 26 P.M.	I	8.2			0.19
June 14, „	1 43 45 P.M.	II	10.4	35		0.71
Jnly 25, „	2 50 55 A.M.	I	7.1	25		0.11
Sept. 16, 1908.	2 09 27 P.M.	I	8.6	—		0.29
Dec. 26, 1909.	9 02 05 P.M.	I	12.6	2		0.28
April 13, 1910.	9 56 15 P.M.	I	8.5	25		0.48
June 28, „	10 55 51 P.M.	III	7.3	55		2.00
March 11, 1911.	10 17 58 P.M.	III	8.2	62		1.80
Nov. 5, „	6 00 10 P.M.	III	12.3	30		6.70
Aug. 6, 1912.	10 21 38 A.M.	I	6.5	16		0.07
Jan. 13, 1914.	7 14 15 P.M.	I	9.6			0.33
March 5, „	9 39 39 P.M.	I	10.3	46		0.18
Aug. 2, „	8 59 58 P.M.	I	8.2	13	2	0.09
July 19, 1915.	4 18 59 A.M.	I	9.0	14	5	0.12
March 29, „	3 54 21 P.M.	I	7.9	—		0.05
April 14, „	10 35 54 A.M.	I	8.8	30		0.52
May 10, „	11 41 39 A.M.	1	7.4	16	3	0.12
May 16, „	0 04 26 A.M.	I	11.3	—	4	0.06
May 19, „	5 45 27 A.M.	III	9.0	45	20	1.20
„ „ „	6 03 03 A.M.	I	9.9	30		0.49
Oct. 8, 1915.	9 18 24 P.M.	I	8.0	—		0.45
Oct. 11, „	11 36 11 P.M.	I	5.6	35	2	0.06

* I. *slight* ; II, *moderate* ; III, *strong*, (p. 58).

Earthquakes with the A-Type Sound. 1907–1922.

Position of Earthquake Origin.	Remarks: Accounts of the Author's Personal Experience.
	Indistinct rumbling sound, (*ton......*) followed by vertical movements. (Observed at Suido-chō, Koishikawa Ward.)
Vicinity of Kasumiga-ura.	Rumbling sound (*do do......*), followed by vertical movements. (*Do.*)
N. part of Shimosa.	Sound, like that caused by the fall of a heavy weight on the ground. (*Do.*)
E. coast of Kazusa.	Sound (*ton*) like that caused by the fall of a heavy weight on the ground, which was not recognized at once as an earthquake, as it was followed by perceptible feeble motion first some 17 sec. later on. (Observed at the Seismological Institute, Hongo.)
	Only a faint rumbling sound. (Observed at Otsuka, Koishikawa Ward.)
	Sound (*ton*), like that caused by a weight falling on the ground, followed immediately by tremors. (*Do.*)
N. part of Shimosa.	Sound (*do do......*), followed by the motion which was vertical at first, but was horizontal later on. (*Do.*)
Do.	Sound (*ton ton......*) perceived for 2 sec. The vertical vibration was moderately strong. (*Do.*)
Bay of Sagami.	Sound (*do do......*), followed by vertical movements. (*Do.*)
E. part of Sagami.	Sound (*ton*), followed by feeble tremors. (Observed at Seis. Institute.)
S.E. corner of Kazusa.	Sound (*ton*), followed by vertical shock 5 sec. later on. (Observed at Mejiro, Koishikawa Ward.)
Near the S.E. coast of the Awa-Kazusa peninsula.	A sudden sound (*don*), like that caused by the fall of a heavy weight on ground. The motion became stronger 17 sec. later on. (*Do.*)
S. part of Kazusa.	Very light sound (*ton*) was followed after 5 sec. by feeble vertical tremblings of a short duration.
N.W. part of Kasumiga-ura.	Sound (*ton*), followed by tremors. (*Do.*)
E. part of Sagami (?).	Sound (*ton*), like that caused by the fall of a heavy weight on ground. The motion was scarcely perceptible. (*Do.*)
Vicinity of Kasumiga-ura.	A strong sound (*ton*), like that caused by a heavy falling body, was followed by a slight rushing noise for about 10 sec. Distinct shaking was felt 12 sec. later on. (Observed at Seism. Institute.)
Boundary of Awa and Kazusa.	A sound (*don*) like that of a sudden uplifting of the ground, followed one or two seconds later by extremely feeble shakings.
Off the S.E. coast of the Awa-Kazusa Peninsula.	*Do.*
E. coast of Kazusa	Sound (*don*), like that caused by the fall of a heavy body on ground, followed by a moderately sharp shock. (Observed at Mejiro, Koishikawa Ward.)
E. coast of Awa-Kazusa peninsula.	Some rumbling sound, follwed by slight shakings.
E. part of Kazusa.	Sound (*ton*), followed by horizontal motion of very short duration. (*Do.*)
E. part of Sagami.	Loud sound (*doon*), which I mistook for a noise caused by a sleeping child striking its foot strongly against a sliding screen. The shaking was very slight. (*Do.*)

Table I. Tokyo Observation of the

Date.	Time of Occurrence.	Intensity.	Duration of Prel. Tremor.	Duration of Sensible Motion.	Total Duration.	Max. 2a.
	h m s		sec.	sec.	min.	mm.
Nov. 20, 1915.	0 45 26 A.M.	I	8.8			0.08
July 11, 1916.	7 11 50 P.M.	II	10.6		6	0.50
Aug. 21, „	11 32 50 P.M.	III	13.3	73	30	4.30
Jan. 29, 1917.	0 25 18 P.M.	II	8.2	30	4	0.50
Feb. 10, „	2 05 06 P.M.	I	6.5	25		0.09
April 9, „	(Morning) A.M.	I	8.9	14		0.11
April 26, „	0 09 36 P.M.	I	6.7	11		0.08
Oct. 5, „	11 22 57 A.M.	I	9.0	38	6	
April 19, 1918.	8 20 46 P.M.	I	5.6	20	3	0.46
May 18, „	0 14 58 A.M.	I	6	20		
Oct. 4, „	11 56 32 A.M.	III	8.5	60	11	2.00
Dec. 19, 1918.	1 01 58 P.M.	I		14		
Jan. 24, 1919.	0 26 07 P.M	II	7.6	30	7	1.40
May 20, „	9 45 22 A.M.	II	9.4	15	4	0.25
Dec. 29, 1921.	11 06 50 P.M.	I	5.5	16	2	0.35
June 15, 1922.	4 07 52 P.M.	I	7.6	(Short)	1	0.064
Aug. 25, „	4 45 35 A.M.	II	8.2	30	8	0.125

Earthquakes with the A-Type Sound. *(Continued.)*

Position of Earthquake Origin.	Remarks: Accounts of the Author's Personal Experience.
S.E. part of Kazusa.	Sharp loud sound (*doon*), followed by shakings. (*Do.*)
Off the S. coast of Kazusa-Awa peninsula.	Loud sound, like a distant gun booming, followed by quick vibrations. (*Do.*)
Vicinity of the town of Ota at the boundary of Hitachi and Shimotsuke.	Rumbling sound (*do do......*), accompanied by quick vertical jerks. Simultaneously crowed the pheasant in the neighbouring garden. (*Do.*)
Off the S. coast of the Miura peninsula, Sagami.	Sharp sound (*ton*), like that caused by the fall of a heavy body on ground, followed by tremors. The motion became stronger later on. (Observed at the Seism. Institute.)
Vicinity of Kmagai, in the N.E. part of Musashi.	Sound (*ton*), followed by vertical tremors. The motion became horizontal 12 sec. after. (*Do.*)
At Kasumiga-ura.	Sound (*ton*), which seemed to proceed from N.W. to S.E. The motion was just sensible. (Observed at Zoshigaya).
W. part of Sagami.	Sound (*ton*), followed by very feeble tremors. (Observed at Seism. Institute.)
W. part of Musashi.	Loud sound (*doon*), like that caused by a heavy body falling on ground The motion was horizontal and became stronger 9 sec. after. (*Do.*)
Central part of Musashi, about 40 km. to the N.W. of Tokyo.	Very loud detonative sound, like a gun booming, immediately followed by feeble tremors, chiefly vertical. (Observed at Zoshigaya.) This was a proper *meido*, or *jinari* (earth-sound), which was mistaken by some people for the effect of explosion of a gun-powder magazine, on account of the loudness.
	Feeble sound (*ton*), like that caused by a falling weight, followed by very slight tremors. (*Do.*)
S.E. part of Kazusa.	Sudden loud sound (*ton*), like that caused by the fall of a heavy body on ground, immediately followed by the shakings. (Observed at Seism. Institute.)
	Slight sound (*ton*), followed by gentle shakings. (*Do.*)
To the W. of Kasumiga-ura.	Loud sound, like that caused by the fall of a heavy body on ground accompanied by the vertical motion. The direction of the principal horizontal shaking was E.W. (*Do.*)
To the W. of Kasumiga-ura.	Loud sound (*don*), like that caused by the fall of a heavy stone on ground. (*Do*) The sound was perceived also at the office of the *Yamato Shinbun* in the Kyobashi Ward.
N.E. part of Musashi, some 35 km. to N. 20° W. of Tokyo.	Loud sound (*don*), followed by the slight tremblings of the ground. (Observed at Zoshigaya.) At the Jiji Shinpo office, in Minami Nabe-cho (Kyobashi Ward), the sound was mistaken for that of a powder explosion. Mr. T. Kato, at Ryusenji-cho (Shitaya Ward), perceived the shock as a loud sound like that caused by the fall of a heavy body on ground, being the loudest he has experienced in Tokyo.
	Slight sound (*ton*), like that of a small weight falling on the ground, followed a few seconds later by extremely feeble shakings.
S.W. corner of Hitachi, 60 km. to the N.N.E. of Tokyo.	Loud sound like that caused by the fall of a heavy body on ground, accompanied by purely vertical shakings. (Felt at Zoshigaya.) Some people mistook the disturbance for the effect of a powder magazine explosion.

Table II. Tokyō Observation of the

Date.	Time of Occurrence.	Intensity.	Duration of Prel. Tremor	Duration of Sensible Motion.	Total Duration.	Max. 2a.
	h m s		sec.	sec.	min.	mm.
Feb. 22, 1907.	9 56 22 P.M.	I	7.8	20		0.16
March 13, ,,	0 38 33 A.M.	I	7.3	65		0.46
July 10, 1908.	9 44 30 P.M.	I	8.8	15		0.19
Sept. 10, ,,	8 41 21 P.M.	I	7.0	40		0.26
Sept. 25, 1909.	11 53 07 P.M.	I	7.0			0.25
Nov. 14, ,,	4 A.M.	I	8.6	40		
Sept 14, 1910.	3 31 08 A.M.	I	7.7	40		1.20
Feb. 17, 1912.	1 48 34 A.M.	II	14.0		10	0.60
Dec. 31, ,,	11 26 14 P.M.	I	25.5	30		1.73
March 10, 1913.	1 41 33 P.M.	I	7.4	47	6	0.90
April 13, 1915.	7 45 21 P.M.	I	9.0	10		0.85
,, ,, ,,	7 49 24 P.M.	I	8.6	40		1.70
Aug. 7, ,,	10 45 12 A.M.	III	9.0	30	14	2.00
Aug. 12, ,,	4 11 10 A.M.	II	10.0	15		1.00
Aug. 28, 1916.	0 42 55 A.M.	I	9.4	35		0.14
March 5, 1917.	6 38 25 A.M.	I	8.9	20		0.14
June 1, 1919.	8 34 27 A.M.	II	10.0	25	11	1.50
Dec. 5, 1920.	4 45 40 A.M.	II	9.6	60	10	1.20
Feb. 14, 1921.	0 00 37 A.M.	II	10.8	30	20	4.70
July 1, 1922.	11 28 02 A.M.	I				

Earthquakes with the B-Type Sound. 1907-1922.

Position of Earthquake Origin.	Remarks: Accounts of the Author's Personal Experience.
Vicinity of Kasumiga-ura, in N. part of Shimosa.	A slight rushing sound, immediately followed by feeble but sharp tremblings. (Observed at Suido-chō, Koishikawa Ward.)
N. part of Shimosa.	Slight rushing sound, accompanied by tremors. (*Do.*)
Do.	Feeble rushing sound, like that of wind, followed immediately after by very slight motion. (*Do.*)
Do.	Rushing sound, like that of wind, followed by gentle shakings. (*Do.*)
In Tokyo. Bay.	Rushing sound, followed after 1 sec. by slight motion. (Observed at Hitotsubashi, by Mr. H. Suzuki.)
Vicinity of Kasumiga-ura.	Sound like that of violent wind, followed by slight motion. (Observed at Yanagi-cho, Koishikawa Ward, by Mr. H. Gen.)
E. coast of Kazusa.	Rushing sound like that of wind. (Observed at Otsuka, Koishikawa Ward.)
Off the coast of Hitachi.	Preceded by sound like that of a distant wagon passage.
Off the S.E. coast of the Kazusa-Awa peninsula.	Rushing sound, like that of wind. (*Do.*)
Off the W. coast of the same peninsula.	Faint rushing sound, followed by tremors felt 1 sec. after. (*Do.*)
Off the E. coast of Kazusa	Faint rushing sound. The motion was felt 2 sec. later on. (Observed at Mejiro, Koishikawa ward.)
Do.	Rushing sound, like that due to the passage of a motor-car, accompanied by tremors, and followed by shakings 2 or 3 sec. later on. (*Do.*)
S. part of Shimotsuke.	Rushing sound, like that of wind, heard toward the E., followed 2 sec. after by quick vibrations. (*Do.*)
S.E. coast of Kazusa.	Slight rushing sound, followed by horizontal shaking. (*Do.*)
E. part of Kazusa.	Low rushing sound, somewhat like that of wind. The motion was felt 3 sec. later on. (*Do.*)
Central part of Kazusa.	Faint rushing sound, accompanied by doubtful shakings. The motion became distinct 12 sec. after. (Observed at Zoshigaya)
Vicinity of Mount Tsukuba, 70 km. to N. 24° E. of Tokyo.	Sound like that of wind blowing heard toward the N.E., accompanied simultaneously by shakings mixed with vertical motion.
Boundary of Hitachi, Shimosa, and Shimotsuke, 70 km. to N. 20°E. of Tokyo	Rushing sound perceived at the commencement. The first vertical displacement was distinct and directed downwards.
Boundary of Kai and Sagami, 75 km. to S. 51° W. of Tokyo.	Sound like that of wind blowing perceived at the commencement. The first vertical displacement was downwards.
	A prolonged dull rushing sound, followed 3 sec. later by very slight motion.

A-TYPE SOUND EARTHQUAKES.

5. Intensity of A-type sound. The intensity of the A-type sound, which is perceived in the different parts of the city of Tokyo irrespective of the nature of soil, does not depend simply on the magnitude of the earthquake or the amplitude of motion. It often happens that a loud detonative sound of this type accompanies quite insignificant earth tremblings, forming a class of natural phenomenon well-known in Japan as "meido" or "jinari" (earth-sound). Below I mention a few cases of the pronounced A-type earthquake sound perceived in Tokyo.

6. Earthquake of April 19, 1918, at 8. 20. 46 P.M. The sound, which was very loud and like the booming of a gun, was followed by slight movements for about 20 sec. According to the tromometer registers, the preliminary tremor lasted 5.2 sec. and the principal portion lasted 25 sec., the total duration being about 3 min. The maximum motion was only 0.46 mm. Several people actually mistook this "meido" for a powder magazine explosion. As the initial displacement of the earthquake motion was directed toward S.57°E. and accompanied by an upward motion, the origin of disturbance must have been situated in the central part of Musashi, some 35 km. to the N.57°W. of Tokyo.

The vertical motion register at Hitotsubashi indicates, as is diagrammatically illustrated in fig. 3, the maximum movements $a_0=0.055$ mm. upwards and $2a'_0=0.105$ mm. downwards, while the $2a_1$ was only 0.06 mm. The register at Hongo also shows the max. upward displacement $a_0=0.066$ mm. at the commencement, the $2a_1$ being 0.09 mm. The actual seismograms are reproduced on Pl. V.

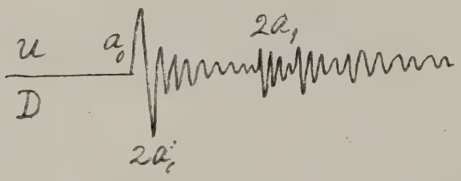


Fig. 3. Diagrammatic Representation of the Vertical Motion of the Earthquake of April 19, 1918. (Hitotsubashi.)

In the horizontal components, the first displacement of the preliminary tremor was 0.06 mm., and the maximum motion in the principal portion was 2.8 mm.

7. Earthquake of Dec. 29, 1921, at 11. 06. 50 P.M. The "meido," which was one of the loudest experienced in Tokyo during the last 20 years or so, was perceived as such at the hilly hard ground portion (for example, Zoshigaya) as well as at the soft soil portion (for examples, Minami-Nabecho in the Kyobashi Ward, and Ryusenji-cho in the Shitaya Ward). Several persons were alarmed at the sound and mistook it for a powder magazine explosion. The preliminary tremor lasted 5.5 sec., the very first horizontal displacement being directed towards the N.E., and accompanied by an upward motion. The earthquake was small (max. hor. motion =0.37 mm.) and the principal portion lasted 16 sec., the total duration being 2^m 4'. The origin was in the N.E. part of Musashi about 35 km. to the N.20°W. from Tokyo.

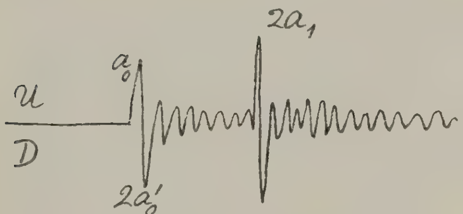


Fig. 4. Diagrammatic Representation of the Vertical Motion of the Earthquake of Dec. 29, 1921.

The initial displacement of the vertical component, diagrammatically illustrated in fig. 4, was a_0= 0.025 mm. upwards, while the maximum range of motion in the principal portion was $2a_1$ =0.055 mm. (See Pl. V.) In each of the horizontal component tromometer with short time scale, the register consisted apparently of a single sudden movement, as is illustrated in fig. 5. In a quicker time scale register, however, the motion consisted of the preliminary tremor *ps* and the max. vibration at the commencement of the principal portion, as in fig. 6.

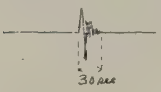


Fig. 5.

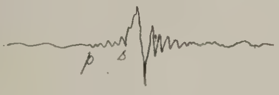


Fig. 6.

According to the ordinary Gray-Ewing type seismograph with an open time scale, the movements were as follows :—

Vertical Compt.	T=0.103 sec.,	$2a_1$=0.05 mm.
E.W. Compt.	T=0.21 ,,	$2a_1$=0.024 ,,
N.S. Compt.	T=0.22 ,,	$2a_1$=0.022 ,,

8. Earthquake of Aug. 25, 1922, at 4. 45. 35 A.M. The present author, who was awoke at the time, perceived first a sound like that caused by the fall of a heavy body on the ground, accompanied by purely vertical shakings. After the preliminary tremor, 8.2 sec. in duration, the principal portion began with another similar sound, again accompanied by vertical movements, mixed with horizontal motion. The sound was indeed so distinct that some people supposed the disturbance to be the effect of a powder magazine explosion. The total duration of the earthquake was about 8 min., of which the sensible portion lasted 30 sec. According to the tromometer diagrams, the 1st horizontal displacement of the earthquake motion was 0.013 mm. and directed toward S.W.S., accompanied by an upward motion. This places the seismic origin at the radial distance of about 60 km. to the N.E.N. of Tokyo. In conformity with the characteristic of a sound earthquake belonging to the seismic region around the lake of Kasumiga-ura and Mount Tsukuba, the initial upward notion was quite large (a_0=0.105 mm.) and formed the greatest amplitude in the whole vertical component. The maximum vertical motion near the commencement of the principal portion was 2a=0.125 mm. (See fig. 15.) The maximum horizontal motion was about 1 mm.

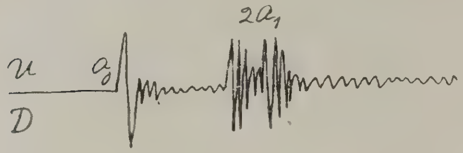


Fig. 7. Diagrammatic Representation of the Vertical Motion of the Earthquake of Aug. 25, 1922.

At the seismological station of Tsukuba ($\varphi=36^\circ 12' 39''$N., $\lambda=140^\circ 6' 36''$E.), this earthquake was first perceived as a loud noise, followed by vertical movements which caused the doors to rattle; the motion being moderately strong. According to the tromometer diagrams (magnification=120), the maximum motion was 0.25 mm. (E.W.) and the total duration was $5^{m}\ 30^{s}$, and the duration of the preliminary tremor was 5.6 sec.; the first displacement being directed toward N.43°E. The origin was therefore situated at the radial distance of about 41 km. to the S.43°W. of the town of Tsukuba.

Combining the observation in Tokyo with that at Tsukuba, the epicentre may be fixed at $\varphi=36^\circ 5'$N., $\lambda=139^\circ 57'$E., namely, at a point about 47 km. to the N.E.N. of Tokyo, in the valley of the Kinu-gawa, near the boundary of the S.W. part of Hitachi and the N.W. part of Shimosa. According to the method explained in the " Seismological Notes," No. 2, the focal depth is found to be 37 km.

9. Earthquake of Oct. 4, 1918, at 11. 56. 32 A.M. The earthquake, which was felt in Tokyo with a moderate strength, and whose preliminary tremor lasted 8.5 sec., originated in the S.E. part of Kazusa. It was initiated by a loud sound like that caused by the fall of a heavy body on the ground, and accordingly the vertical motion began with a sudden displacement a_0=0.13 mm. downwards, followed by the counter motion of $2a'_0$=0.23 mm.,

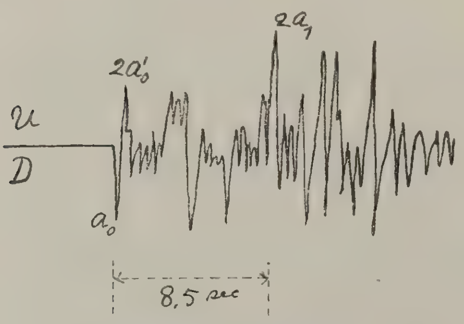


Fig. 8. Diagrammatic Representation of the Vertical Motion of the Eqke. on Oct. 4, 1918.

with the period of about 0.36 sec. The maximum motion in the principal portion was $2a_1=0.35$ mm. In the horizontal components, the first displacement of the preliminary tremor was quite small and only 0.0067 mm., directed toward the S.60°E. The maximum horizontal motion in the principal portion was 2.0 mm. (See fig. 23.)

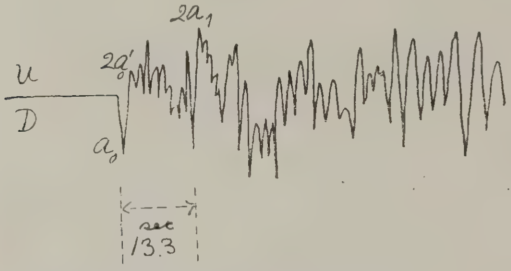
10. Earthquake of Jan. 24, 1919, at 0. 26. 07 P.M. The earthquake was accompanied by a loud sound like that of a heavy weight falling on the ground. The principal portion of the horizontal component was composed of well-defined vibrations of $T=0.26$ sec., mixed with traces of slower movements of $T=0.55$ sec., the max. 2a being 1.2 and 0.7 mm. respectively in the E.W. and the N.S. directions. The vertical component was, however, composed of the much quicker vibrations, of $T=0.086$ sec., max. $2a=0.044$ mm., mixed with slow movements of $T=0.5$ sec. apprx.; there being also traces of extremely minute vibrations ($2a=0.007$ mm.) of $T=0.033$ sec. apprx., corresponding to the frequency of about 30 per sec.

The vertical tromometer registers began with a well defined downward displacement $a_0=0.125$ mm., followed by the counter motion of $2a'_0=0.2$ mm.; the predominating period in the preliminary tremor being $T=1.33$ sec. In the principal portion, the max. motion was $2a_1=0.237$ mm. and the predominating period was $T=0.47$ sec. Toward the end, the motion had the periods of 1.4 sec. and of 0.7 sec. A careful examination of the diagrams shows that the vertical and the horizontal component movements began rigorously at the same time moment, (namely, 13.5 sec. after a time cutting mark). Yet the horizontal component began with a motion far smaller than the corresponding vertical displacement, the initial displacements in the E.W. and the N.S. directions being respectively 0.009 mm. and 0.008 mm. On the other hand, the maximum motion in the principal portion of the horizontal components was much greater than that in the vertical.

	Vertical Component.	E.W. Component.	N.S. Component.
1st Displacement of Prel. Tremor.	0.125 mm.	0.009 mm.	0.008 mm.
Max. Motion in the Princ. Portion.	0.237	1.28	1.14

It is interesting that the vertical motion diagram at Hitotsubashi indicates the preliminary tremor much similar to that at Hongo. Thus the initial motion was a downward displacement of $a_0=0.12$ mm., following by the counter displacement of $2a'_0=0.233$ mm., the predominating period in the preliminary tremor being $T=1.3$ sec. In the principal portion, the max. $2a_1$ was 0.33 mm. and the predominating period was 0.64 sec. Later on there were well defined vibrations of $T=0.87$ sec.

11. Earthquake of Aug. 21, 1916, at 11. 32. 50 P. M. The earthquake was moderately strong and was initiated by a loud rumbling sound, accompanied by quick vertical jerks which caused the pheasant in the neighbouring garden to crow. The preliminary tremor lasted 13.3 sec., the origin being in the vicinity of the town of Ota at the boundary of Hitachi and Shimotsuke. The motion was sensible for 73 sec., the maximum horizontal motion being 4.3 mm.



Ffg. 9. Diagrammatic Representation of the Vertical Motion of the Eqke. on Aug. 21, 1916.

In the vertical component the first displacement was $a_0=0.34$ mm. downwards, followed by the counter upward motion $2a'_0=0.45$ mm. ; the vibration period being 1.1 sec. The max. motion in the principal portion was $2a_1=0.58$ mm. (period=1.1 sec.). From about 47 sec. after the commencement there appeared large slow movements : $2a=1.0$ mm., period $=4.1$ sec.

The first displacement in the horizontal component was 0.2 mm. directed toward N. 28°E. The maximum vibration at the commencement of the principal portion was as follows : 1st displacement=4.0 mm., directed toward S. 39°E. ; 2nd displacement=4.3 mm., toward N. 40°W.

12. Earthquake of May 19, 1915, at 5. 45. 27 A. M. The shock, which was felt in Tokyo with a moderate intensity and was sensible for 45 sec., was accompanied by a sound like that caused by the fall of a heavy body on the ground. The time, at which the sound was heard by me, was noted by my watch to be about 5. 45. 25 A.M., being sufficiently close to the time of commencement of the earthquake as indicated on the tromometer records. The pheasant in the neighbouring garden crowed 16 sec. after my perception of the sound. The preliminary tremor lasted 9.0 sec., and the origin was situated on the eastern coast of Kazusa, about 65 km. to the S.55°E. of Tokyo. The vertical motion began with the downward maximum displacement of $a_0=$ 0.12 mm., followed by the upward movement of $2a_0'=0.13$ mm. The maximum motion at the commencement of the principal portion was $2a_1=$

0.13 mm. The vibration period was 0.52 sec. both at the commencement of the earthquake motion and in the principal portion. (See pls. VII. and VIII.)

Diagramatic Representation of the Vertical Motion. Earthquakes on May 19, 1915. (Hongo.)

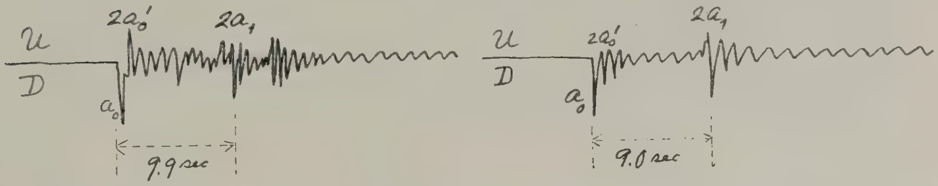


Fig. 10. Earthquake at 6. 03. 02 A. M.

Fig. 11. Earthquake at 5. 45. 27 A M.

In the horizontal components, the first displacement was only 0.0063 mm. toward the S. and the 0.0089 mm. toward the E., with the resultant of 0.011 mm. in the direction of S.55°E. The maximum horizontal motion in the principal portion was 1.2 mm. The earthquake was followed within 8 minutes by two unfelt after-shocks, at 5.49.26 A.M. and 5.53.33 A.M. respectively.

13. Earthquake of May 19, 1915, at 6. 03. 02 A. M. This slight earthquake was accompanied by a sort of rumbling sound, followed by sensible movements for about 30 sec.; being smaller than, but much similar in character to, the preceding earthquake. The preliminary tremor lasted 10.6 sec., and the first horizontal displacement was 0.008 mm. directed toward S.40°E., the origin being situated near the eastern coast of the Awa-Kazusa peninsula, on the boundary of the two provinces. The maximum horizontal motion in the principal portion was 0.49 mm.

In the vertical component, the greatest displacement occurred at the commencement, : $a_0=0.13$ mm, directed downwards; $2a_0'=0.18$ mm. The max. $2a_1$ in the principal portion was 0.15 mm. (See pl. VII.)

There was an unfelt small after-shock at 6.42.21 A.M. Previous to the main earthquake at 5. 45. 27 A.M., there were two small fore-shocks on the 18th, at 2. 51. 35 and 6. 19. 21 P.M. respectively, of which the first was unfelt and the second slightly sensible.

14. Earthquake of Aug. 2, 1914, at 8. 59. 27 P. M. While sitting quietly at my house in the Koishikawa district, I perceived a very faint single sound as that of a foot tread which I took to be an earthquake sound. After 5 seconds there were felt vertical shakings for a short time interval, the pheasant first then crowing two or three times. The preliminary tremor lasted 8.2 sec., and the first displacement was directed toward the S.E. The maximum motion was 0.09 mm., and the principal portion lasted 13.5 sec., the total earthquake duration being 2 minutes. The origin was situated in the S. portion of Kazusa.

15. Earthquake of May 20, 1919, at 9. 45. 22 A. M. The earthquake began with a sound like that of a weight falling on the ground, followed by movements sensible for 15 sec. The horizontal motion at the commencement was 0.002 mm. directed toward S.65°W., accompanied by an upward displacement. The origin was to the S.W. of the lake of Kasumiga-ura. (See Pl. IX.)

16. Earthquake of June 15, 1922, at 4. 07. 52 P. M. This was a small disturbance and was perceived as a very slight sound (*ton*) like that of a small weight falling on the ground. A few seconds later on extremely feeble shakings were felt for a short time interval. According to the tromometer diagrams, the vertical motion began with the maximum displacement (2a=0.02 mm.) at 4. 07. 52 P.M., while the time of commencement of the horizontal motion was, according to the tromometer registers, practically identical, namely, 4. 07. 52½ P.M. The time at which I have perceived the sound was at once noted by my chronometer watch and found to be 4. 07. 52½ P.M. The total earthquake duration was about 60 sec., and the duration of the preliminary tremor was 7.6 sec. The motion at the commencement of the horizontal component was very small, being 2a=0.001 mm. The maximum motion of the principal portion, which occurred immediately after the termination of the preliminary tremor was as follows: Vert., 0.013 mm.; E.W., 0.056 mm.; N.S., 0.031 mm. (See Pl. XI.)

B-TYPE SOUND EARTHQUAKES.

17. Earthquake of Aug. 7, 1915. at 10. 45. 12. A. M. There was first some rushing sound, like that of wind, heard toward the east, followed 2 seconds later by quick vibrations. The earthquake was felt with a moderate intensity, and the maximum horizontal motion was 2.0 mm., the duration of the sensible portion being 30 sec. The origin was situated in the S. part of Shimotsuke.

In the vertical component register, the first displacement was only 0.01 mm., while the maximum motion in the principal portion was 0.15 mm. (See Pl. XVII.)

18. Earthquake of Aug. 12, 1915, at 4. 11. 10 A. M. This was an earthquake of moderate intensity, which began with a slight rushing sound, followed by horizontal shakings. The preliminary tremor lasted 10.0 sec., and the origin was situated near the S. E. coast of Kazusa.

TOKYO OBSERVATION OF LOUD A-TYPE SOUND EARTHQUAKE.

Earthquake of April 19, 1918, at 8.20. 46 P.M.

p......Commencement of Preliminary Tremor.
s......   „   „ Principal Portion.

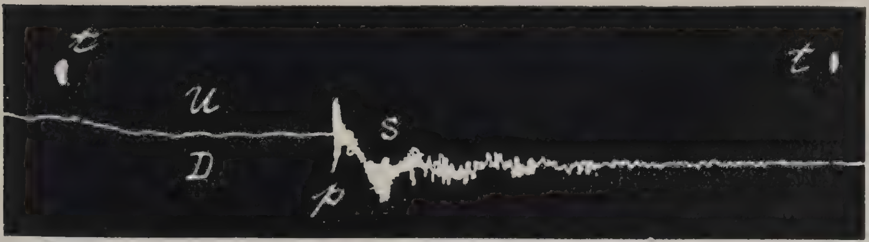


Fig. 12. Vert. Component at Hitotsubashi. Magnification = 88.
t......Successive Minute Mark.

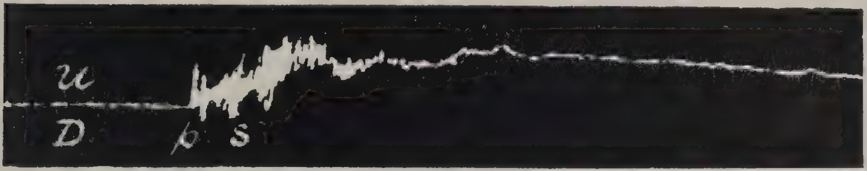


Fig. 13. Vert. Component at Hongo. Magnification = 89.
Time Scale: 1 minute = 106 mm.

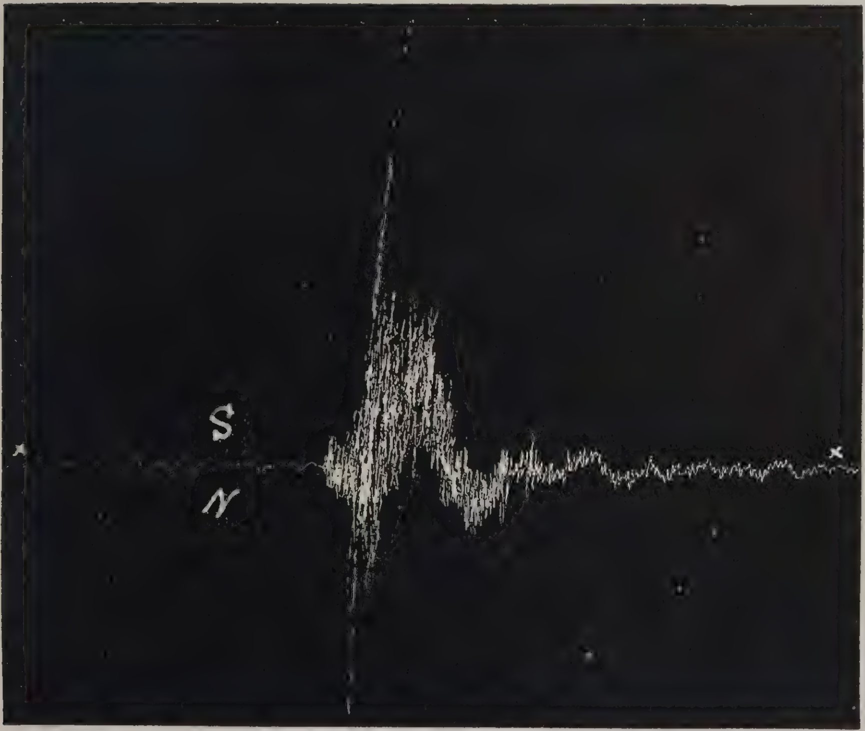


Fig. 14. N.S. Component at Hongo. Magnification = 43.
×......Time (Minute) Cutting.

TOKYO (HONGO) OBSERVATION OF LOUD A-TYPE SOUND EARTHQUAKES: VERTICAL COMPONENT.

p......Commencement of Earthquake.

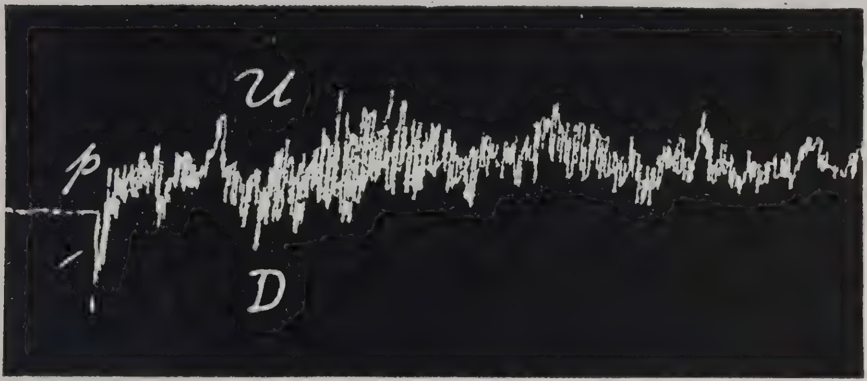


Fig. 17. Earthquake of May 19, 1915, at 6.03.02 A.M.
Magnification = 106. Time Scale: 1 minute = 124 mm.

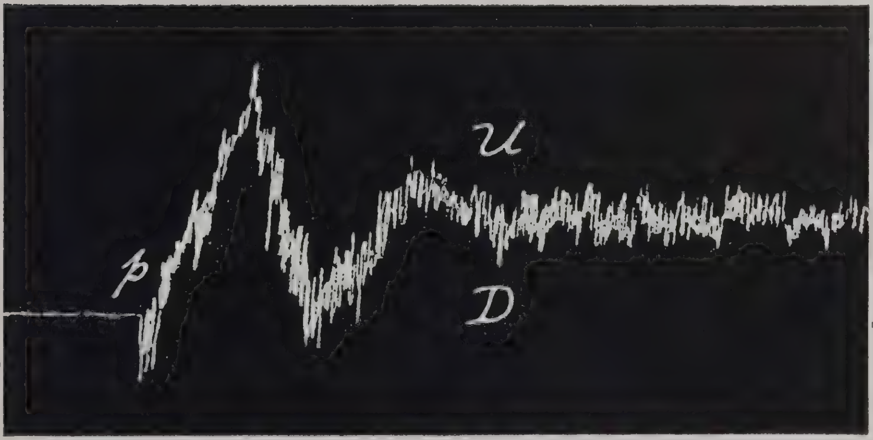
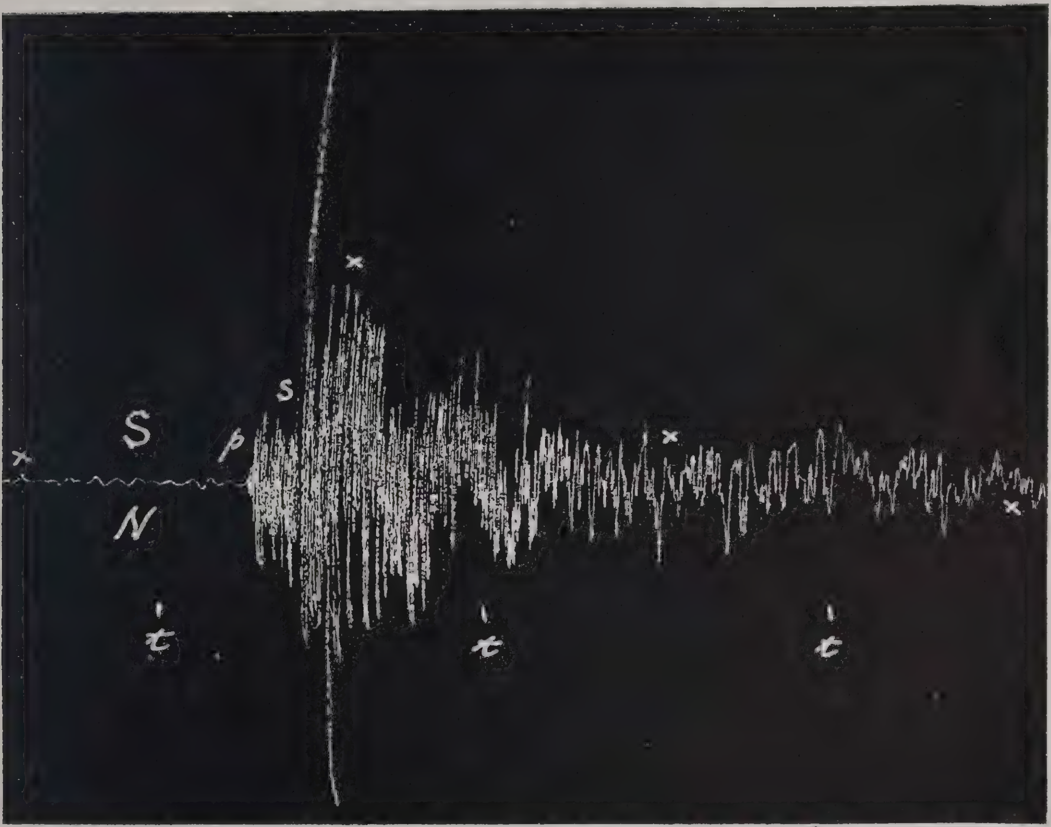


Fig. 18. Earthquake at May 19, 1915, at 5.45.27 A.M.
Magnification = 75. Time Scale: 1 minute = 94 mm.

TOKYO (HONGO) OBSERVATION OF LOUD A-TYPE SOUND EARTHQUAKE.

Fig. 19. Earthquake of May 19, 1915. at 6.03.02 A.M. Horizontal Component.



Magnification = 154 (×)......Minute Cutting.

t......Successive Time (Minute) Mark.

OBSERVATION OF VERTICAL MOTION.

p......Commencement of Preliminary Tremor.
s...... „ „ Principal Portion. (×)......Time (Minute) Cutting.

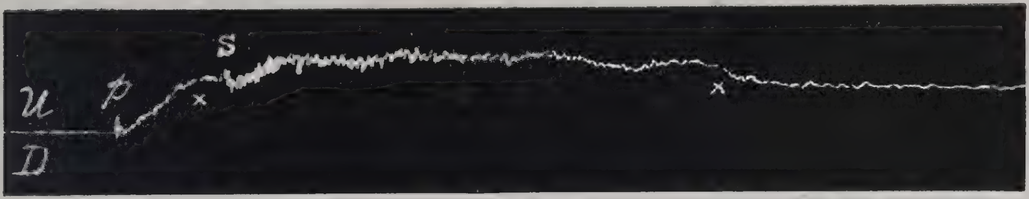


Fig. 20. Tokyo Observation of the Loud A-Type Sound Earthquake on May 20, 1919, at 9.45.22 A.M. Magnification = 61. (Hongo.)

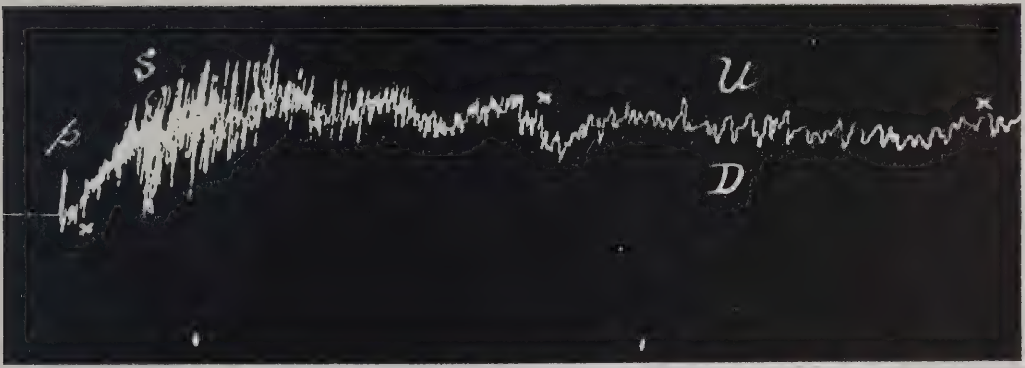


Fig. 21. Tokyo Observation of the B-Type Sound Earthquake on June 1, 1919, at 8.34.27 A.M. Magnification = 50. (Hongo.)

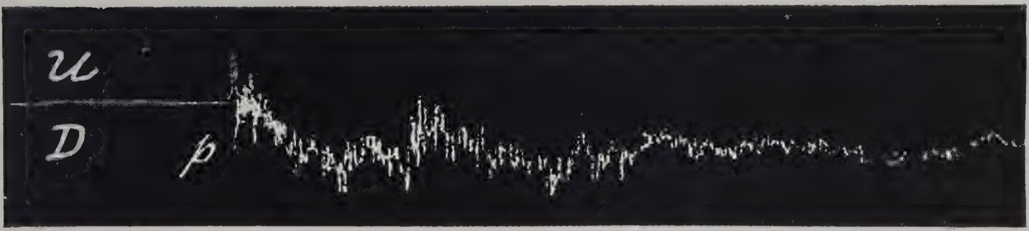


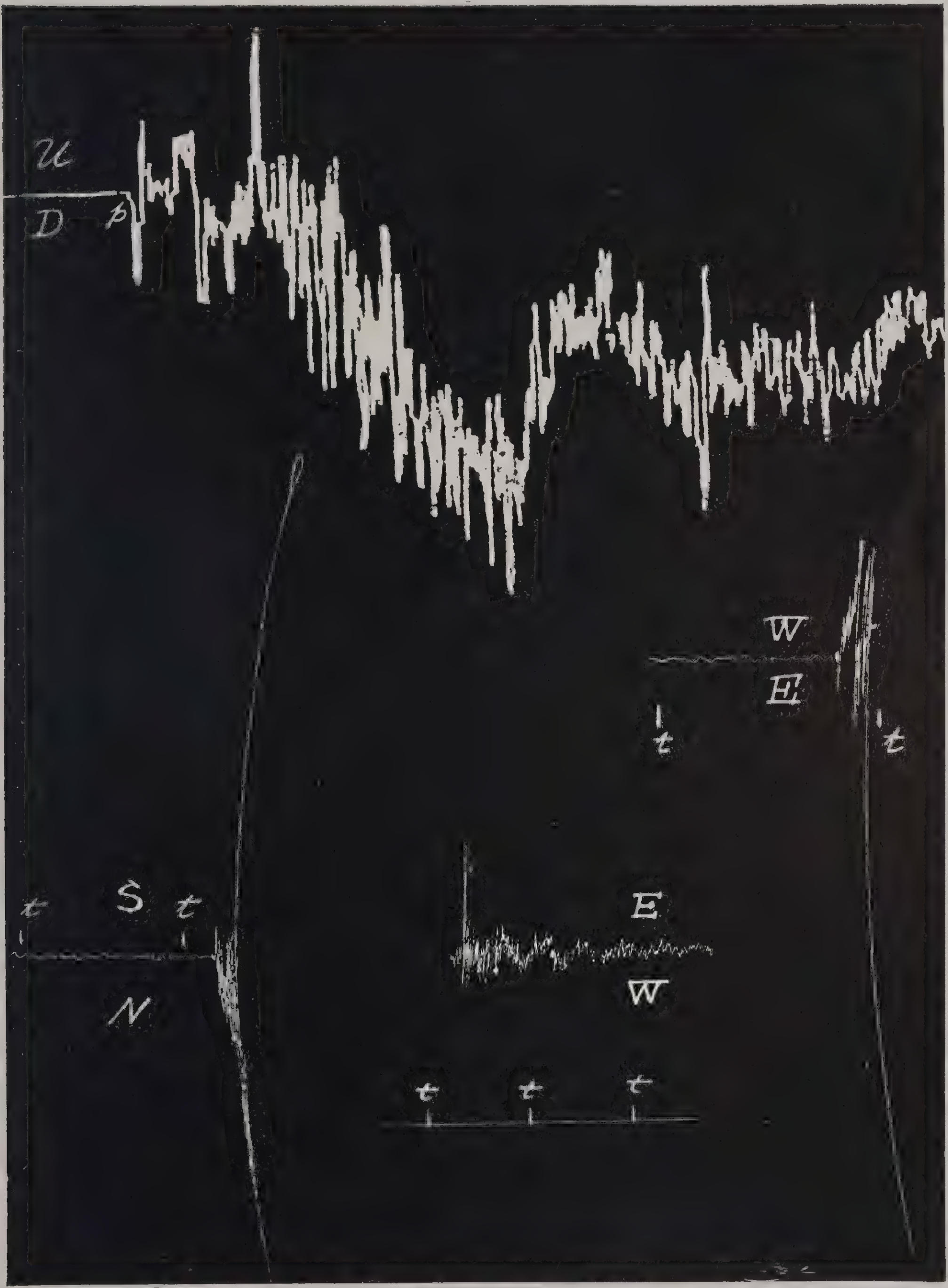
Fig. 22. Choshi Observation of the Earthquake on June 1, 1919, at 8.34.29 A.M. Magnification = 95.

TOKYO (HONGO) OBSERVATION OF EARTHQUAKE WITH LOUD A-TYPE SOUND: VERTICAL AND HORIZONTAL COMPONENTS.

Fig. 23. Earthquake of Oct. 4, 1918, at 11.56.32 A.M.

Time Scale: 1 minute = 124 mm.

Magnification = 103.



Magfn. = 112.

Magfn. = 11.4.

Magfn. = 186.

(t) marks successive minute of time.

TOKYO (HONGO) OBSERVATION OF EARTHQUAKE WITH A SLIGHT A-TYPE SOUND: VERTICAL AND HORIZONTAL COMPONENTS.

Earthquake of June 15, 1922, at 4.07.52P. M.

p......Commencement of Preliminary Tremor.
s...... „ „ Principal Portion.

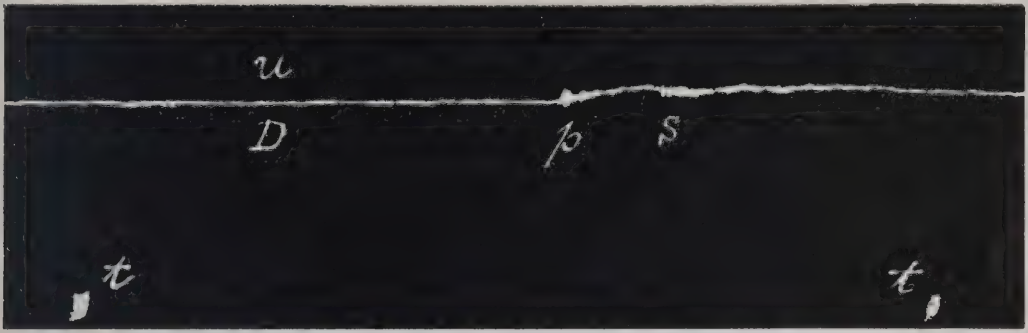


Fig. 24. Vertical Component. Magnification = 95.
t......Time (Minute) Mark.

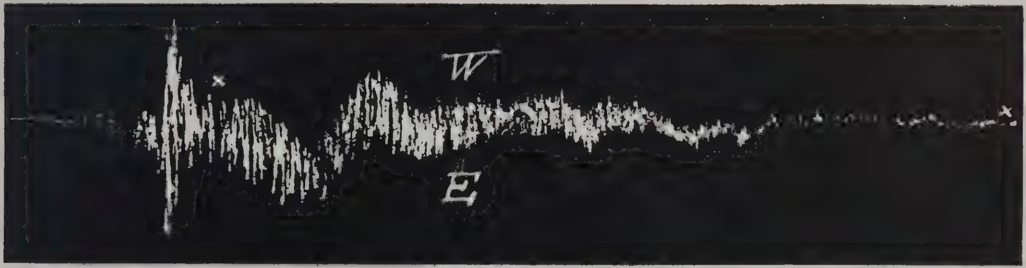


Fig. 25. E.W. Component. Magnification = 537.
(×)......Successive Time (Minute) Cutting.

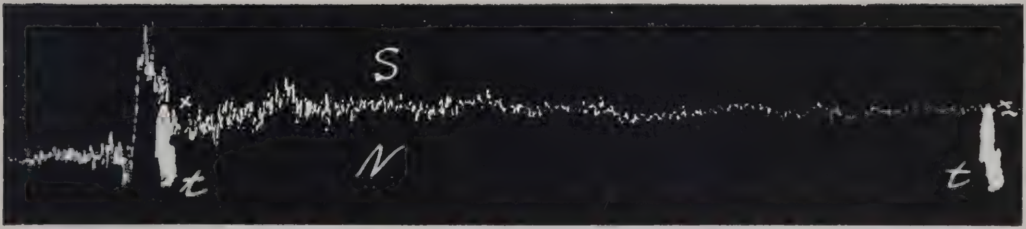


Fig. 26. N.S. Component. Magnification = 540.
(×)......Successive Time (Minute) Cutting.

TOKYO (HONGO) OBSERVATION OF THE EARTHQUAKE OF AUG. 21, 1912, at 11.32.50 P.M. ACCOMPANIED BY A LOUD RUMBLING SOUND.

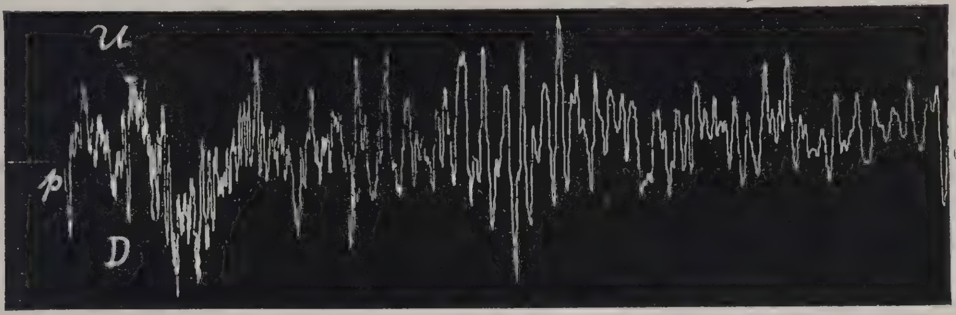


Fig. 27. Vertical Component. Magnification = 32.

p......Commencement of Preliminary Tremor.

Time Scale: 1 minute = 38 mm.

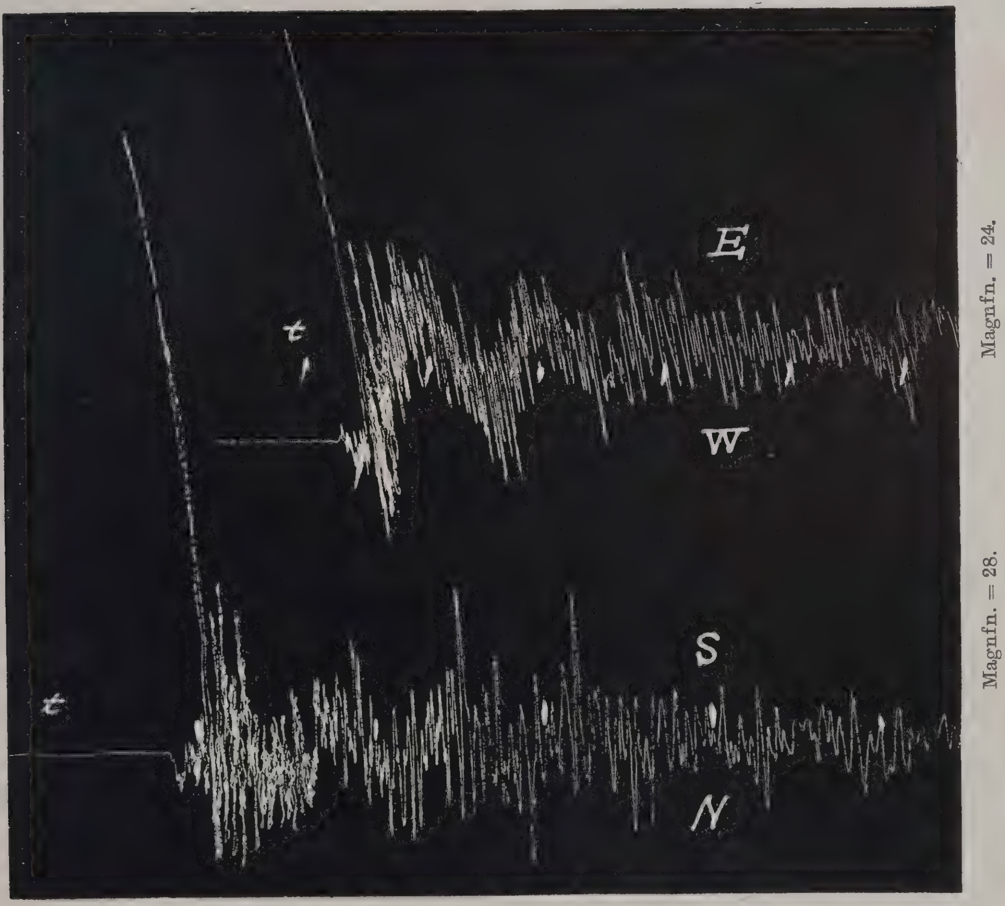


Fig. 28. Horizontal Components.

t......Successive Time (Minute) Mark.

TOKYO (HONGO) OBSERVATION OF THE EARTHQUAKES WITH NO SOUND: VERTICAL COMPONENT.

p......Commencement of Preliminary Tremor.

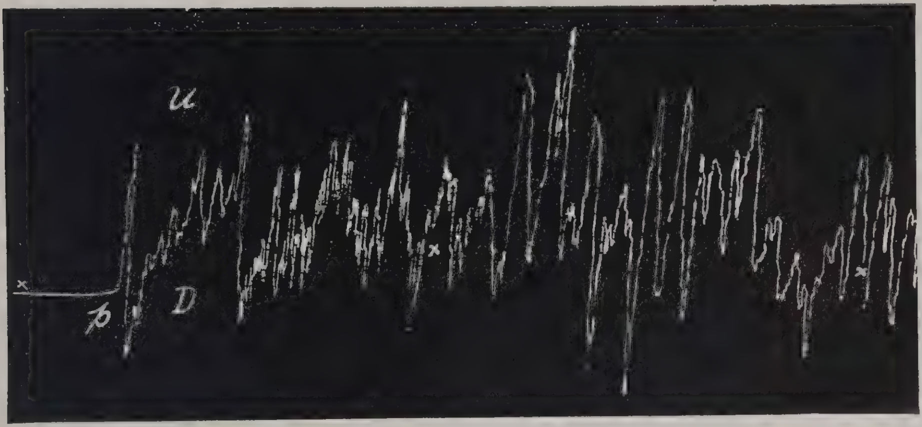


Fig. 29. Earthquake of July 3, 1920, at 11.19.30 P.M.

Magnification = 50.

(×)......Successive Time (Minute) Cutting.

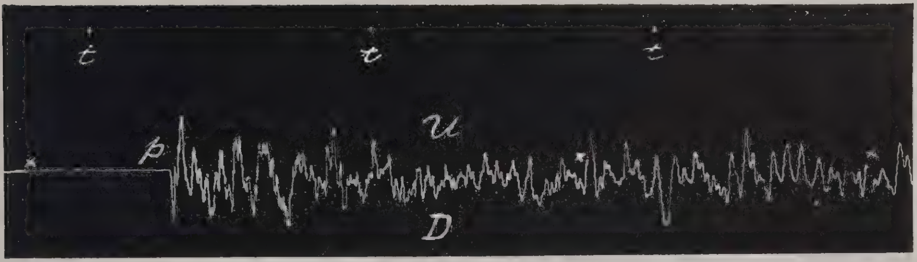


Fig. 30. Earthquake of Nov. 9, 1922, at 5.16.31 A.M.

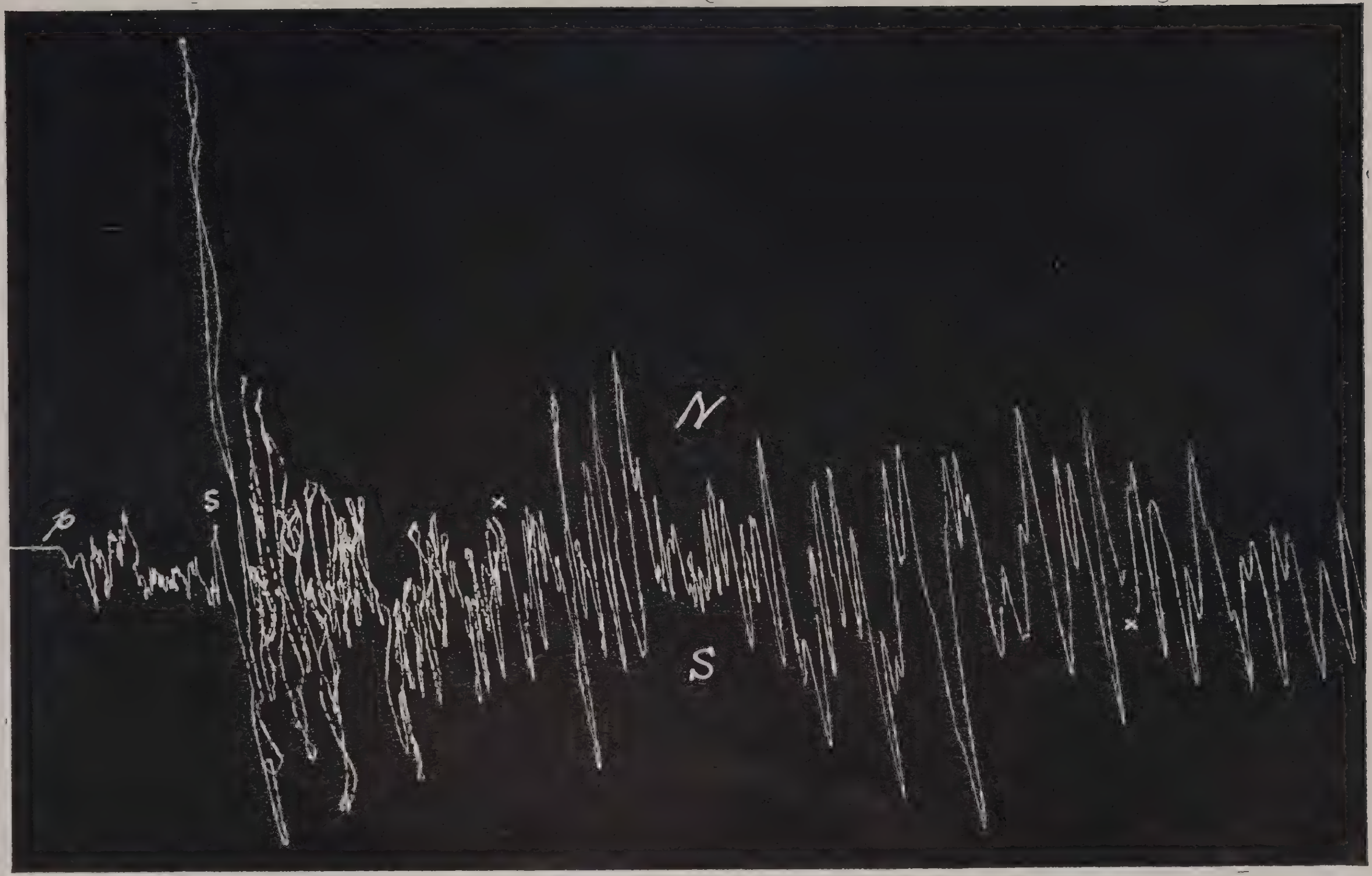
Magnification = 32.

t......Successive Time (Minute) Mark.

(×)...... „ „ „ Cutting.

Fig. 31. Tokyo (Hongo) Observation of the Earthquake of July 3, 1920, at 11.19.30 P.M., accompanied by NO Sound.

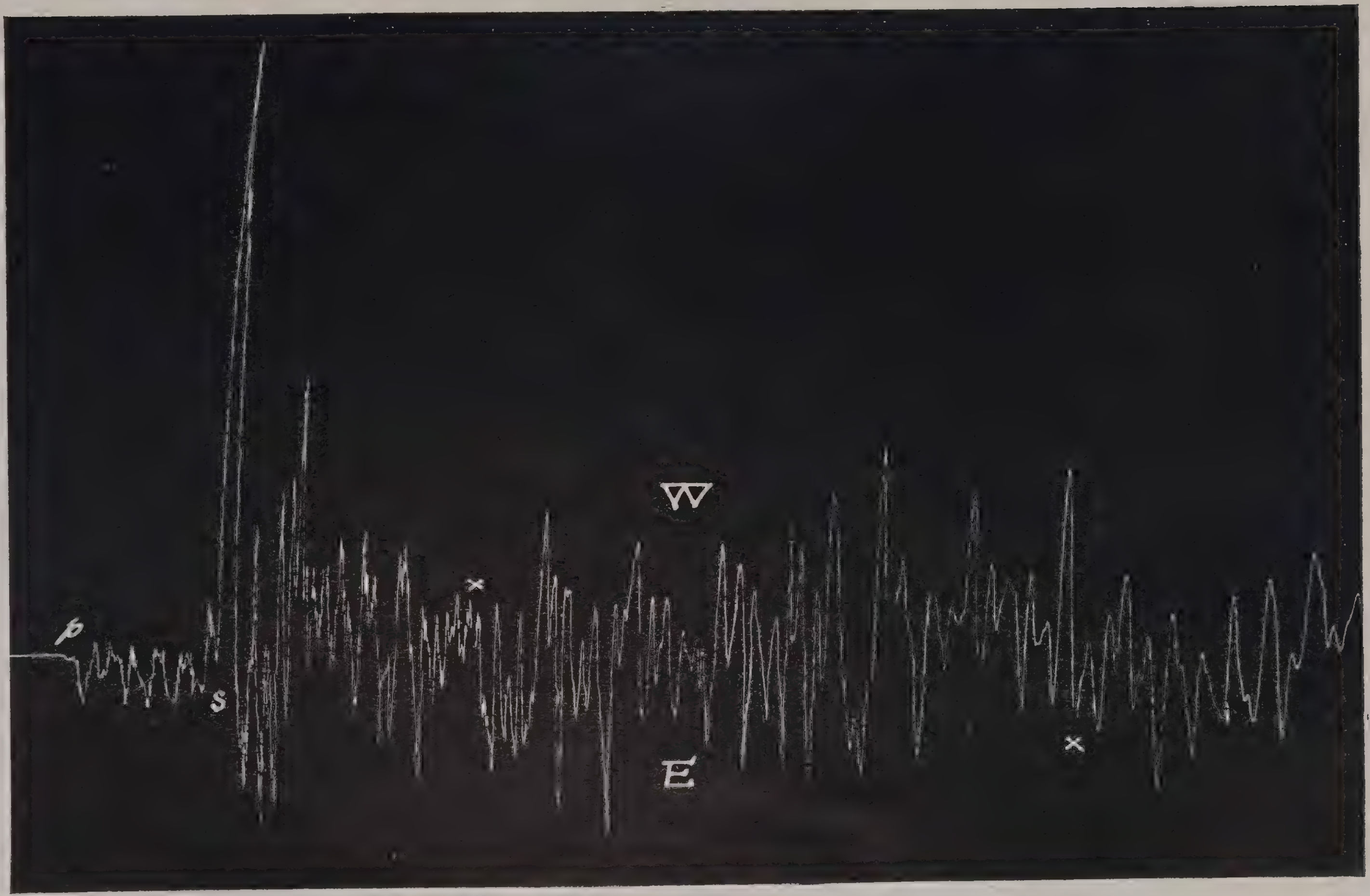
p.........Commencement of Preliminary Tremor.
s.........   „   „ Principal Portion.



N.S. Component. Magnification = 57. (×).........Successive Time (Minute) Cutting.

Fig. 32. Tokyo Observation of the Earthquake of July 3, 1920, at 11.19.30 P.M., accompanied by NO Sound.

p.........Commencement of Preliminary Tremor.
s.........   ,,   ,, Principal Portion.



E.W. Component.   Magnification = 43.   (×)........ Successive Time (Minute) Cutting.

In the vertical component, the first displacement was $a_0=0.043$ mm., directed downwards; while in the principal portion, the maximum motion was 0.15 mm. In the horizontal component the first displacement of the preliminary tremor was 0.007 mm., while the maximum motion in the principal portion was 1.0 mm. (See pl. XVI.)

19. Earthquake of Aug. 28, 1916; 0.42. 55 A. M. In the vertical component, the motion at the commencement was a small slow vibration, of $2a=0.053$ mm., $T=3.0$ sec. The maximum motion in the principal portion was 1.7 mm. (See pl. XVI.)

20. Earthquake of July 1, 1922, at 11. 28. 02 A. M. This extremely small shock, which I have felt while standing in the Seismological Institute by an open window at the N. W. corner of the building, was initiated by a prolonged dull, but distinct, rushing sound, heard toward the N. N. E., like that of a fairly brisk wind blowing. While I were wondering whether it was the report of the explosion of Mount Asama, there were perceived very slight gentle shakings of the floor and the window, some 3 sec. after the occurrence of the sound.

MISCELLANEOUS REMARKS.

21. Time interval between sound and shaking. The A-type sound marks strictly the commencement of the preliminary tremor and is followed at once by the tremblings of the ground. In some cases of the very slight shocks, however, the earth motion remained *unfelt* for a considerable time interval and consequently the sound preceded by several seconds the occurrence of well defiend movements, as in the following examples :—

Earthquake (Intensity *slight*).		Interval between Sound and the well-defined movement.
Sept.	16, 1908	17 sec.
Jan.	13, 1914	5 sec.
March	5, ,,	17
Aug.	1, ,,	5
April	14, ,,	12

The B-type sound, which is not so abrupt in termination as the A-type one, often preceded by an appreciable time interval of 1 to 3 seconds the occurrence of the sensible movements in the preliminary tremor stage, as in the following cases :—

Date.	Earthquake Intensity	Interval between Sound and Sensible Tremors.
Sep. 25, 1909.	*Slight.*	1 sec.
March 10, 1913.	,,	1
April 13, 1915.	,,	2
April 13, ,,	,,	2 or 3
Aug. 7, 1915.	*Moderate.*	2
Aug. 28, 1916.	*Slight.*	3

22. **Duration of preliminary tremor.** The majority of the earthquakes with the A-type sound had a preliminary tremor, whose duration varied between 5.5 sec. and 12.6 sec., with the mean of 8.3 sec., whether the sound was loud or feeble. In the case of the earthquakes with more or less prolonged rumbling sound, the duration of the preliminary tremor was generally a little longer and was 10.3 sec. on the average. (See Table III.)

Table III.

Duration of the Preliminary Tremor of the A-type Earthquakes which were preceded by				
Loud Sound. (*don* or *ton*)		Feeble Sound (*ton*).		Rumbling Sound. (*dodo......*)
sec.	sec.	sec.	sec.	sec.
5.5 (Very loud)	8.6	6.5	8.5	7.3
5.6 (Very loud)	8.8	6.5	8.9	8.2
5.6	8.8	6.7	9.0	10.4
7.1	9.0	7.4	9.6	12.3
7.6	9.0	8.0	11.3	13.3
7.9	9.4	8.2	12.6	
8.2	10.3			
8.2	10.6			
8.5				
Mean............... 8.3		Mean...... 8.6		Mean...... 10.3

The duration of the preliminary tremor of the B-type earthquakes, or those accompanied by a rushing sound, varied with two exceptions between 7.0 sec. and 10.0 sec., with the mean of 9.0 sec., as follows :—

7.0 sec.	8.9 sec.	25.4 sec.
7.0	9.0	
7.3	9.0	
7.4	9.4	
7.7	9.6	
7.8	10.0	
8.6	10.0	
8.6	10.8	
8.8	14.4	
Mean............9.0		

Thus there is no material difference in the duration of the preliminary tremor for the earthquakes with the A-type sound and for those with the B-type sound. The duration of the preliminary tremor was always under 13.3 sec., which corresponds to the focal distance of about 98 km.; in the single exception the duration being 25.4 sec., with the corresponding radial distance of 188 km. The A-type sound was loudest in the two earthquakes whose preliminary tremor lasted 5.5 and 5.6 sec. respectively. It is evident that the sound is loudest at the epicentral district, as has been well illustrated in the "meido," or "jinari," in 1899 at the neighbourhood of the hot spring place of Arima, (province of Setts).

23. Note on earthquakes not accompanied by sound. Some of the earthquakes observed in Tokyo, which were not accompanied by sound, had the diagrammatic character of the A-type disturbance, the first vertical displacement being large and of a quite sudden occurrence. Two examples of the newest dates are given next.

Earthquake of July 3, 1920, *at* 11. 19. 30 P.M. The earthquake, felt with a moderate intensity, began with a horizontal displacement of 0.05 mm. directed toward S. 25° E. accompanied with a well-defined upward motion of 0.41 mm. The preliminary tremor lasted 16.2 sec., and the whole earthquake duration was minutes. The observations at the meteorological observatories of Mito and Choshi were as follows :—

	Intensity.	Time of Occurrence.	Duration of Prel. Tremor.
Mito.	*Moderate.*	11.19.35 P.M.	16.5 sec.
Choshi.	Unfelt.	11.19.42 ,,	24.0 ,,

The seismic origin was situated about 120 km. to the N. 25° W. of Tokyo, near the boundary of the two provinces of Shimotsuke and Kotske. (See fig. 34.)

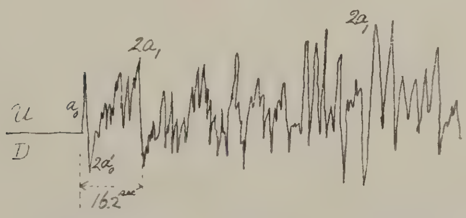
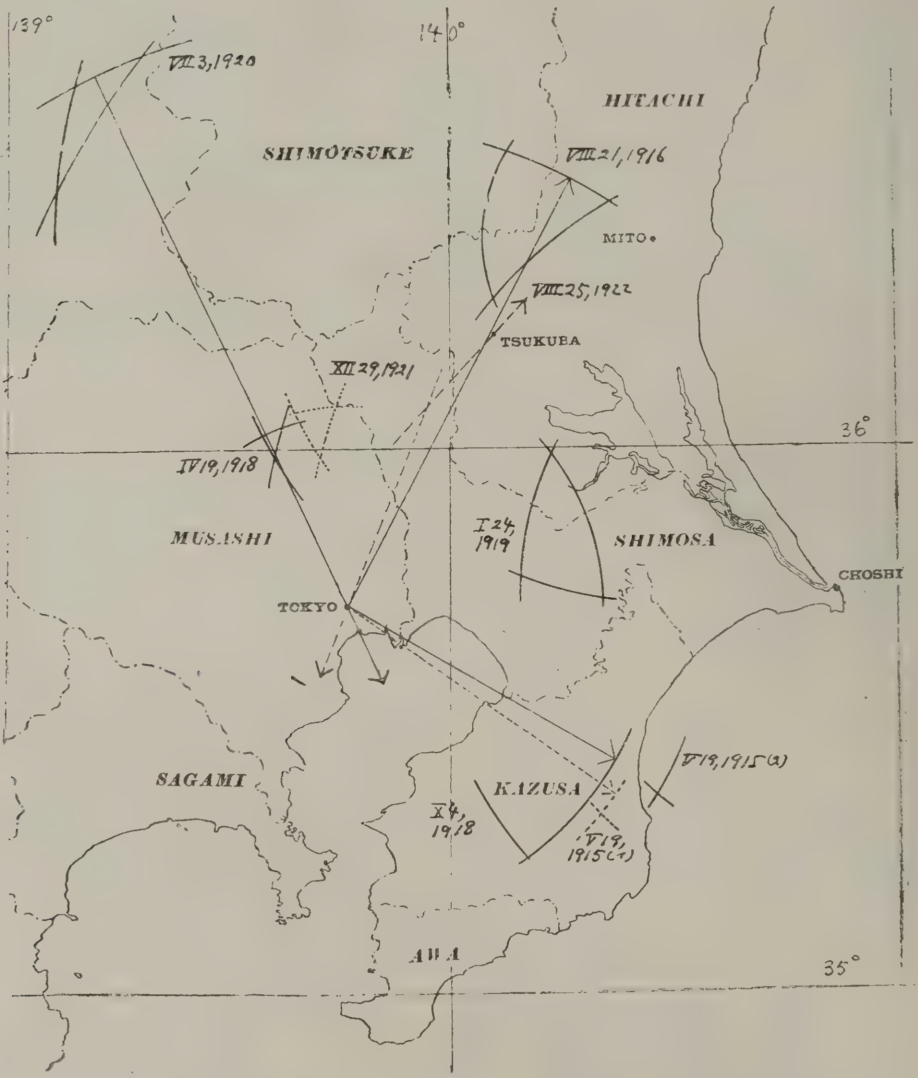


Fig. 33. Diagrammatic Representation of the Eqke. on VII 3, 1920.

The vertical motion was composed of slow movements (T = 1.7 sec., T = 2.6 sec.), but began with a well-defined upward displacement of a_0 = 0.41 mm., followed by the downward motion of $2a_0'$ = 0.57 mm. The principal

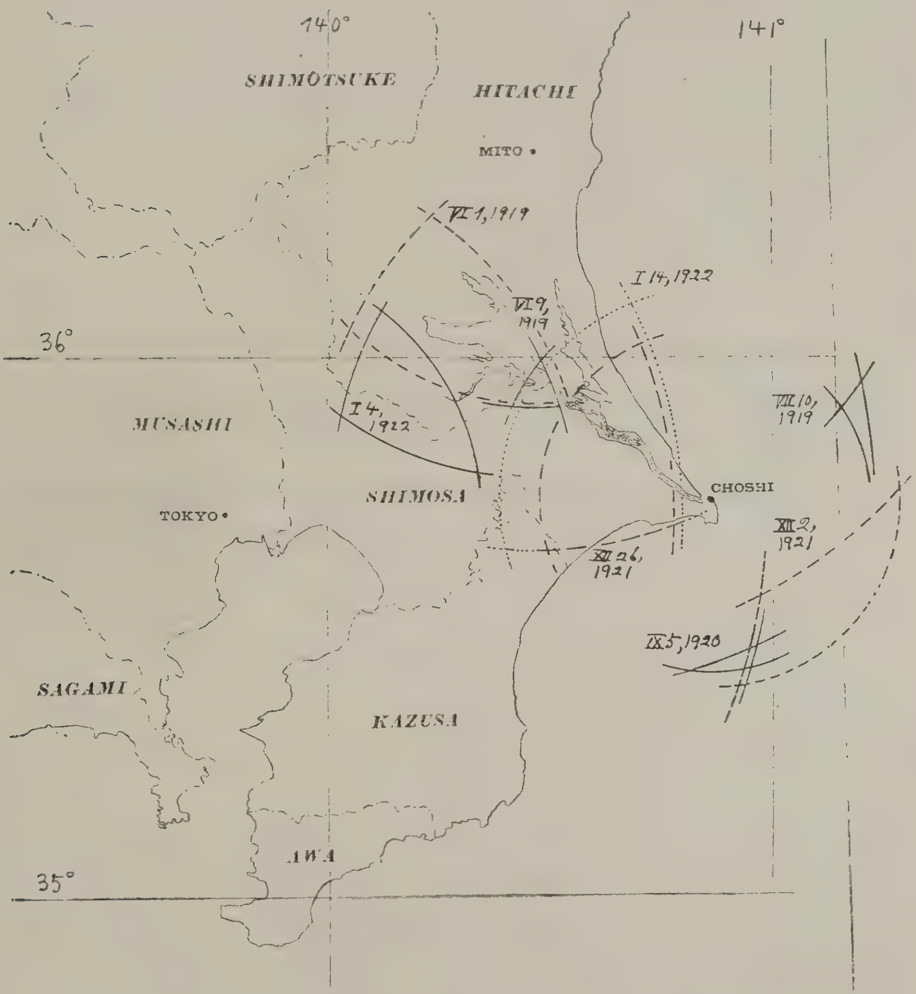
Fig. 34. Map showing the Location of Centres of the Earthquakes with the Loud A-type Sound perceived in Tokyo.



The date of each earthquake is affixed to the triangle formed by the arcs drawn about Tokyo (Seismological Institute), Mito, and Choshi as centres with the radii corresponding to the central distances. Each of the arrows indicate the direction of the first displacement in Tokyo for the earthquake concerned. (In the case of the eqke. on Aug. 25, 1922, the direction at Tsukuba is also given.)

The earthquake on July 3, 1920 has been taken as an instance of a rather distant shock which was accompanied by no sound, but whose motion was of the character of an earthquake with the A-type sound.

Fig. 35. Map showing the Location of Centres of the Earthquakes observed at Choshi, each of which began with a well defined Vertical Motion.



The date of each earthquake is affixed to the triagle formed by the arcs drawn about Tokyo (Seism. Institute), Mito, and Choshi as centres with the radii corresponding to the central distances.

portion began with a downward motion of $2a = 0.55$ mm., and the maximum motion of $2a_1 = 0.81$ mm. occurred about 65 sec. after the commencement of the earthquake.

Earthquake of Nov. 9, 1922, *at* 5. 16. 31 A.M. This was a slight earthquake, sensible for 18 sec. According to the tromometer registers, the preliminary tremor lasted 14 sec., the first displacement being directed toward the E. slightly N. and accompanied by a downward motion. The principal portion lasted 1 minute and the maximum horizontal motion was 1.4 mm., the total duration being 15 minutes. The seismic origin was situated about 100 km. to the E. 4° N. of Tokyo, namely, off the coast of the town of Choshi. The vertical motion began with the downward displacement of $a_0 = 0.021$ mm. The maximum motion in the subsequent portion was $2a_1 = 0.25$ mm.

Had the origins of the two earthquakes above mentioned been nearer to Tokyo, say, of radial distances under 70 km., there would have been in each case an A-type sound at the commencement of the earthquake motion.

24. Distribution of the seismic origins. The geographical distribution of the origins of the different earthquakes was as follows :—

Location of Origin.	A-type Eqkes.	B-type Eqkes.
(i) Awa-Kazusa Peninsula, especially its E., S.E., and S. coasts...	8	8
(ii) Vicinity of Kasumiga-ura, N. part of Shimosa, and S. corner of Shimotsuke.	10	6
(iii) Sagami, Bay of Sagami, and vicinity of Hakone.	6	0
(iv) W. and Central parts of Musashi, and Tokyo Bay....	2	1

From the above classification it will be seen that the two sound types may accompany earthquakes originating from any of the different seismic regions around Tokyo. Again, earthquakes with sound originate from the hilly Tertiary regions of the Awa-Kazusa peninsula as well as from under the soft alluvium plain about the Kasumiga-ura. Hence it is evident that the nature of the surface ground at the epicentral region has nothing to do either with the production of the A-type earth-sound, or with the distinction of the sounds into the two types of (A) and (B) categories.

Table IV. Position of the Epicentres of the Earthquakes accompaned by well-defined A-type Sound.

The figures enclosed in brackets indicate the intensity, as follows : 0……Insensible ; I……*Slight* ; II……*Moderate* ; III……*Strong*.

Date.	Time of Occurrence (in Tokyo.)	Duration of Prel. Tremor.			Position of Earthquake Origin.
		Tokyo.	Choshi.	Mito.	
	h m s	sec.	sec.	sec.	
IV 14, 1915.*	10 35 54 A.M.	8.8 (I)	13.5 (0)	— (I)	Vicinity of Kasumiga-ura, 65 km. to S. 55° E. of Tokyo.
V 19, ,, *	5 45 27 A.M.	9.0 (II)	8.9 (0)	11.0 (I)	E. part of Kazusa, 60 km. to S. 55° E. of Tokyo.
,, ,,	6 03 02 A.M.	9.9 (I)	7.5 (0)	9.0 (I)	E. coast of Kazusa, 65 km. to S. 72° E. of Tokyo.
X 11, ,, *	11 36 11 P.M.	5.6 (I)	—	—	E. part of Sagami.
XI 20, ,, *	0 45 26 A.M.	8.8 (I)	10.4 (0)	— (I)	S. E. part of Kazusa.
XII 11, 1916.*	7 11 50 P.M.	10.6 (I	17.0 (0)	10.0 (I)	Off the coast of Kazusa.
VIII 21, ,, *	11 32 50 P.M.	13.3 (III)	12.2 (0)	4.7 (III)	Boundary of Hitachi and Shimotsuke, 92 km to N. 27° E. of Tokyo.
I 29, 1917.*	0 25 18 P.M.	8.2 (II)	14.4 (0)	13.0 (0)	Off the S. coast of Miura Penisula.
II 10, ,,	2 05 06 P.M.	6.5 (I)	8.5 (0)	—	Vicinity of Kasumiga-ura.
IV 9, ,,	4 56 47 A.M.	8.9 (I)	10.2 (0)	7.0 (I)	*Do.*
IV 26, ,,	0 09 36 P.M.	6.7 (I)	—	—	W. part of Sagami.
XI 5, ,, *	11 22 57 A.M.	9.0 (II)	9.9 (0)	14.0 (I)	W. part of Msashi. (?)
IV 19, 1918.*	8 20 46 P.M.	5.2 (II)	15.8 (0)	12.0 (0)	N. E. part of Msashi, 38 km. to N. 25° W. of Tokyo.
X 4, ,, *	11 56 32 A.M.	8.5 (III)	11.2 (0)	12.0 (I)	N. part of Kazusa, 48 km. to S. 60° E. of Tokyo.
I 24, 1919.*	0 26 07 P.M.	7.0 (II)	8.6 (0)	10.0 (I)	To the S W. of Kasumiga-ura, 48 km. to N. 75° E. of Tokyo.
V 20, ,, *	9 45 22 A.M.	9.4 (II)	12.8 (0)	12.0 (0)	To the W. of Kasumiga-ura.
VII 3, 1920.†	11 19 P.M.	16.2 (II)	24.0 (0)	16.5 (II)	E. part of Kotsuke, 117 km. to N. 26° W. of Tokyo.
XII 29, 1921.*	11 06 50 P.M.	5.5 (I)	14.6 (0)	11.0 (II)	N.E. part of Msashi, 35 km. to N. 10° W. of Tokyo.
VIII 25, 1922.*	4 45 35 A.M.	8.2 (II)	—	—	N. part of Shimosa, 47 km. to N.E.N. of Tokyo.

* Very loud sound.

† Accompanied by no sound, but initiated by a distinct vertical motion.

Table V. Recent Tokyo Observation of Sensible Earthquakes unaccompanied by Audible Sound.

Date.	Time of Occurrence.	a_0 = 1st Displt of Eqke. Motion.	Duration of Prel. Tremor.	Total Duration.	Max. 2a.	Position of Eqke. Origin.
SUBMARINE, IN THE VICINITY OF CHOSHI.						
	h m s	mm	sec.	m.	mm.	
V 22, 1913.	5 36 00 A.M.	0.68 → N. 88° E. 0.69 Down.	15	35	4.0 (H) 1.4 (V)	Due E. of Choshi.
V 29, „	7 12 30 P.M.	2.6 → E. 5° S. 1.8 Down.	15	60	5.1 (E.W.) 3.3 (N.S.) 3.6 (V)	S.E. of Choshi.
I 8, 1914.	7 54 00 P.M.	0.26 → E. 11° N. 0.32 Down.	13	15	1.7 (E.W.) 1.7 (N.S.)	N.E. of Choshi.
IV 25, 1915.	2 10 07 A.M.	→ E. Down.	16		2.6 (H)	Vicinity of Choshi.
S.E. PART OF KAZUSA.						
II 12, 1914.	3 58 50 A.M.	S.E., Down.	7.8	10	0.6	S.E. Part of Kazusa.
X 7, 1915.	7 13 39 P.M.	S E. Down.	8.0	3	0.45	E. Part of Kazusa.
VIII 10, 1917.	3 24 26 A.M.	S.E. Down.	9.0	10	0 37	„
IV 18, 1918.	11 35 32 A.M.	S 49°E. Down.	8.7	15	0.70	„
XII 15, 1913.	11 02 35 A.M.	0.7 → S. 70° E. Down.	7.7	24	11.0	E. Coast of Kazusa.
XI 3, 1916.	3 04 05 P.M.	S.52°E. Down.	8.4	5	0.5	E. Part „
IV 7, 1918.	5 45 08 A.M.	S.E. Down.	8.0	3	0.3	„
II 12, 1919.	11 27 47 A.M.	E.11°S. Down.	7.9	5	0.4	N. Part of Kazusa.
X 8, 1916.	2 08 51 A.M.	S.23°E. Down.	6.0	5	0.2	W. part of Kazusa.
I 26, 1912.	4 29 50 P.M.	N.W. Up.	9.6	20	4.0	E. Coast of Awa
V 31, 1912.	9 30 11 P.M.	N.28°W. Up.	8.3	10	Slight.	N. Part of Awa.
X 16, 1913.	9 17 29 A.M.	N.W. Up.	9.6	5	0.2	E. Coast of Kazusa.
X 12, 1914.	2 28 54 A.M	W.N.W. Up.	9.2	10	0.23	„
V 31, 1912.	0 31 03 A.M.	N.W. Up.	10.0	20	4.6	Off the E. Coast of Awa.
II 10, 1914.	1 05 23 A.M.	S.40°E. Down.	11.8	15	1.8	Off the S.E. „
IV 7, 1919.	2 28 36 A.M.	W.N W. Up.	10.6	10	0.4	Off the N.E. „
VICINITY OF TSUKUBA-SAN.						
X 17, 1917.	3 03 42 A.M.	N.E. Down.	9.0	20	5.5	Vicinity of Tsukuba-san.
XI 6, 1917.	2 40 10 A.M.	N.33°E. Down.	8.9		0.3	*Do.*

Table V. Recent Tokyo Observation of Sensible Earthquakes unaccompanied by Audible Sound. (*Continued.*)

Date.	Time of Occurrence.	a_0 = 1st Displt of Eqke. Motion.	Duration of Prel. Tremor.	Total Duration.	Max. 2a.	Position of Eqke. Origin.
VICINITY OF KASUMIGA-URA.						
	h m s		sec.	m.	mm.	
IX 30, 1912.	9 34 22 P.M.	N.75°E. Down.	10.7	10	0.89	To the S.E. of Kasumiga-ura.
III 5, 1915.	3 11 39 P.M.	N.E. Down.	11.3	5	0.15	To the S.W. of Kasumiga-ura.
X 26, 1915.	10 55 02 P.M.	S.39°W. Down.	6.7	2	0.08	To the W. of Kasumiga-ura.
III 4, 1919.	9 04 06 P.M.	N.E. Down.	8.5	10	3.0	Near the N.W. shore of Kasumiga-ura.
N. PART OF MUSASHI, ETC.						
X 18, 1912.	8 02 45 P.M.	N.30°W. Down.	13 6	15	—	N.W. Part of Msashi (?)
X 19, 1912.	7 23 48 P.M.	S.E. Up.	12.	6	0.55	
III 29, 1914.	2 17 02 A.M.	S. nearly. Up.	10.6	20	0.77	S. Part of Shimotske.
X 8, 1914.	10 38 28 A.M.	S.S.E. Up.	9.3	9	0.85	Boundary of Musashi, Shimotsuke and Kotsuke.
IV 17, 1918.	6 26 50 A.M.	N.W.	7.7	3	0.12	N.W. Part of Musashi.
SAGAMI AND W. PART OF MUSASHI.						
IV 6, 1915.	3 39 49 A.M.	N.E. Up.	5.2	7	0.7	N.E. Part of Sagami.
VI 6, 1917.	1 28 45 A.M.	N.N.E. Up.	13.8	20	0.13	In the Sagami Bay.
IV 19, 1918.	7 22 27 A.M.	E.N.E. Up.	14.4	15	0.9	”
OFF THE E. COAST OF THE MAIN ISLAND, ETC.						
XII 5, 1912.	2 33 02 A.M.	N.E. Down.	15.6	12	0.2	Off the coast of Hitachi.
IV 4, 1915.	10 54 45 A.M.	W.53°S. Up.	22.0	30	0.4	Off the N.E. coast of Main Island.
VI 25, 1915.	1 18 39 A.M.	S.60°W. Up.	14.4	10	0.11	Off the coast of Hitachi.
VIII 8, 1916.	1 24 51 P.M.	N.E. Down.	16.	—	2.3	*Do.*
VI 10, 1917.	7 41 23 A.M.	N.E. Down.	15.6	20	1.1	Vicinity of Mito.
VI 25, 1915.	1 18 39 A.M.	S.60°W. Up.	14.4	10	0.2	Off the coast of Hitachi.
VII 26, 1918.	5 50 41 A.M.	E.N E. Down.	24.5	30	5.0	*Do.*
XII 20, 1920.	5 11 27 A.M.	S.W. Up.	19.5	40	—	*Do.*
I 14, 1916.	11 57 31 A.M.	S.33°W. Up.	19.1	10	0.3	Boundary of Hitachi and Iwaki.

Table VI. Observation of the Earthquakes, whose Motion at Choshi indicated well defined Vertical Vibration at the Commencement.

Date.	Observing Place.	Time of Occurrence.	Intensity.*	Duration of Prel. Tremor.	Position of Eqke. Origin.
		h m s		sec.	
July 26, 1918.	Tokyo.	5 50 41 A.M.		24.5	Off the coast of Hitachi.
	Choshi.	5 50 25	0	7.0	
	Mito.	5 50 31		9.0	
July 30, 1918.	Tokyo.	3 00 41 A.M.	0	17.5	*Do.*
	Choshi.	3 00 35	0	6.0	
	Mito.	3 00 38	I	8.0	
June 1, 1919.	Tokyo.	8 34 27 A.M.	II	10.0	Vicinity of Mount Tsukuba.
	Choshi.	8 34 29	I	11.0	
	Mito.	8 34 22	III	7.0	
June 9, 1919.	Tokyo.	8 14 54 A.M.	I	9.7	To the S. of Kasumiga-ura.
	Choshi.	8 14 51	I	5.3	
	Mito.	8 14 53	I	7.0	
July 10, 1919.	Tokyo.	1 20 54		18.0	35 km. to the E.E.N. of Choshi.
	Choshi.	1 20 43	II	4.4	
	Mito.	1 20 47			
,,	Tokyo.		0		*Do.*
	Choshi.	1 24 19	II	4.4	
	Mito.				
,,	Tokyo.		0		*Do.*
	Choshi.	1 47 26	I	4.1	
	Mito.				
June 4, 1919.	Tokyo.	6 55 48 P.M.	0	9.6	To the S.E. of Kasumiga-ura.
	Choshi.	6 55 39	I	4.9	
	Mito.	6 55 44	I	5.0	
May 13, 1920.	Tokyo.	6 53 36 A.M.	III	17.0	Off the S.E. coast of the Awa-Kazusa Peninsula.
	Choshi.	6 53 42	0	23.5	
	Mito.	6 53 42	II	24.0	

* The intensity of motion of ordinary, or non-destructive, earthquake is indicated as follows: 0, insensible; I, *slight*; II, *moderate*; III, *strong*.

Table VI. (*Continued.*)

Date.	Observing Place.	Time of Occurrence.	Intensity.	Duration of Prel. Tremor.	Position of Eqke. Origin.
Sept. 5, 1920.	Tokyo.	5 44 56 A.M.	0	15.4	Submarine, to the E. of Choshi.
	Choshi.	5 44 40	0	4.7	
	Mito.	5 44 49	0	15.0	
Oct. 15, 1920.	Tokyo.	4 33 36 A.M.	0	12.1	
	Choshi.	4 33 24	0	5.7	
	Mito.	4 33 36	0		
Dec. 3, 1920.	Tokyo.	8 40 27 A.M.	I	21.8	Off the coast of Hitachi.
	Choshi.	8 40 14	II	11.8	
	Mito.	8 40 17	I	12.0	
Dec. 8, 1920.	Tokyo.	11 04 29 A.M.	0	18.7	*Do.*
	Choshi.	11 04 15	0	10.9	
	Mito.	11 04 16	I	15.0	
Jan. 10, 1921.	Tokyo.	3 56 12 A.M.	I	23.3	*Do.*
	Choshi.	3 57 4	0	12.2	
	Mito.	3 56 16	0	17.0	
Dec. 2, 1921.	Tokyo.	2 27 40 A.M.	0	15.0	Off the E. coast of Kazusa.
	Choshi.	2 27 27	0	9.8	
	Mito.	2 27 39	0	14.0	
Dec. 26, 1921.	Tokyo.	10 15 09 P.M.	0	12.4	To the S.E. of Kasumiga-ura.
	Choshi.	10 14 59	I	4.7	
	Mito.	10 15 08	I	11.0	
Jan. 4, 1922.	Tokyo.	3 32 59 P.M.	I	7.1	N. part of Shimosa.
	Choshi.	3 33 02	0	10.4	
	Mito.	3 32 58	I	9.0	
Jan. 14, 1922.	Tokyo.	2 04 06 P.M.	0	12.6	To the S.E. of Kasumiga-ura.
	Choshi.	2 03 53	I	5·8	
	Mito.	2 04 08	I	11.0	

Table VII. Observation of the Vertical Motion at Choshi.

a_0 and $2a'_0$ are respectively the 1st and 2nd displacements of the vibration at the commencement of the earthquake motion; $2a_1$ denotes the maximum range in the subsequent stage corresponding to the principal portion of the horizontal component.

Date.	Time of Occurrence.	Duration of Preliminary Tremor.	Total Duration.	1st Vibration.		$2a_1$
				a_0	$2a'_0$	
[1st Vertical Displacement directed downwards.]						
		sec.	m	mm.	mm.	mm.
VII 10, 1919.	1 20 43 A.M.	4.4	4	0.78*	1.30	—
,,	1 24 19 ,,	4.4	$2\frac{1}{2}$	0.23*	0.20	0.18
,,	1 47 26 ,,	4.1	1	0.10*	0.11	0.09
V 13, 1920.	6 53 42 A.M.	23.5	8	0.21	0.70	1.07
IX 5, ,,	5 44 40 A.M.	4.7	1	0.08*	0.10	0.03
XII 3, ,,	8 40 14 A.M.	11.8	7	0.12	0.24	0.38
XII 8, ,,	11 04 15 A.M.	10.9	$1\frac{1}{2}$	0.01	0.03	0.03
I 10, 1921.	3 57 04 A.M.	12.2	7	0.15	0.26	0.78
XII 2, ,,	2 27 27 A.M.	9.8	$1\frac{1}{3}$	0.03	—	0.11
[1st Vertical Displacement directed upwards.]						
VI 4, 1919.	6 55 39 P.M.	5.8	$\frac{2}{3}$	0.04*	—	0.03
VI 9, ,,	8 14 51 A.M.	5.3	1	0.15*	—	0.25
X 15, 1920.	4 33 24 A.M.	5.7	1	0.02*	—	0.02
XII 26, 1921.	10 14 59 P.M.	4.7	$\frac{3}{4}$	0.02*	—	(Small).
I 4, 1922.	3 33 02 P.M.	10.4	$1\frac{1}{6}$	—	0.05	0.03
I 14, ,,	2 03 53 P.M.	5.8	1	0.03*	—	0.04

25. Observation at Choshi. An examination of the tromometer diagrams obtained at the meteorological observatory of Choshi ($\varphi=35°44'11''$N., $\lambda=140°51'38''$E.) also shows that the vertical motion there often begins with a prominent, and sometimes the maximum, displacement. The time of occurrence, the duration of the preliminary tremor, and the position of the epicentre for earthquakes of this sort are given in Table VI. As will be seen from Table VII, the vertical component of the earthquakes, with the preli-

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(*) marks the case in which the 1st displacement (a_0) was greater than the amplitude (a_1) or even the range of motion ($2a_1$) in the subsequent principal portion.

minary tremor of the duration under 6 seconds, began with the maximum vibration, whose first displacement a_0, to be regarded as the single amplitude, was generally greater than the maximum range, or double amplitude ($2a_1$), in the subsequent stage corresponding to the principal portion of the horizontal motion. Similar peculiarity is also the case with the sound earthquakes perceived in Tokyo, and is probably true of the observations in other places. The movements at the commencement of the preliminary phase is anyhow of the longitudinal wave, and it is quite natural that the vertical component should begin with a prominent, or the maximum, vibration, as the longitudinal motion ought to be vertical at the epicentral area.

26. Distribution of seismic origins and the nature of focal disturbance. As explained in the Seismological Notes, No. 2, the recent earthquakes sensible in Tokyo originated chiefly in the following four seismic districts: (I), the Awa-Kazusa peninsula and the outside sea bottom; (II), vicinity of Mount Tsukuba and the lake of Kasumiga-ura; (III), the Hakone and Ashigara districts and the vicinity; and (IV), a zone off the eastern coast of the Main Island. The first three active regions are mutually continuous and form an annular zone, 30 to 40 km. in width, and 30 to 75 km. radially distanct from Tokyo as centre. The semi-destructive earthquakes of Dec. 8, 1921, and of April 26, 1922, took place respectively at the S.E. extremity of the region (II) and in the Uraga channel between the regions (I) and (III); these being localities on the seismic zone in question where the frequency is at present small and consequently favourable for the production of occasional strong earthquakes. No earthquake has taken place in recent years from the immediate vicinity of the city of Tokyo, (T), namely, the low Musashi plain and the Tokyo bay, included in a circle of radius of about 60 km., within the circular seismic zone I, II, and III. From this it may be suggested that the district (T) is different in dynamical respect from the whole or part of the surrounding districts (I), (II), and (III). Of the latter the most active (I) district, continued to (III), is essentially mountainous and of the Tertiary formation, while (II), is composed partly of the Tertiary and granitic formations and partly of Quaternary formations. As will be seen from the descriptions in §§ 5–16 and from fig. 2, the A-type earthquakes and others of similar character with the initial *upward* vertical displacement originated in and about the (II) district, while those with the initial *downward* vertical displacement originated in and about the (I) district and its north-east continuation surrounding the (II) district on the eastern side.

For the sake of reference I give in Table V the results of the recent Tokyo observations relating to the sensible earthquakes *not* accompanied by sound. As will be seen from Table VIII, in the majority of the shocks with origin in the Awa-Kazusa peninsula and the vicinity of Choshi, the initial motion was directed downwards, while in the cases of those with the origin in the N. and W. parts of Musashi and in the province of Sagami it was directed upwards. These facts accord in a measure with the results relating to the earthquakes with sound. The parallelism does not hold with respect to the shocks originating in the vicinity of Kasumiga-ura and Mt. Tsukuba.

Table VIII. Tokyo Observations of Sensible Earthquakes *without* Sound: Duration of Preliminary Tremor.

Seismic Origin.	Initial Vertical Motion directed *upwards*.		Initial Vertical Motion directed *downwards*.	
Awa-Kazusa peninsula, and the vicinity of Choshi.	8.3 sec. 9.2 9.6 9.6 10.0 10.6		6.0 sec. 7.7 7.8 7.9 8.0 8.0 8.4 8.7 9.0	11.8 sec. 13 15 15 16
N. and W. Parts of Musashi, and Sagami.	5.2 9.3 10.6	12.0 sec. 13.8 14.4		13.6
Vicinity of Kasumiga-ura and Mt. Tsukuba.	6.7		8.5 8.9 9.0	10.7 11.3

To return to the earthquakes felt in Tokyo, which were accompanied by a well defined A-type sound, it may be remarked that the Awa-Kazusa seismic district (I) is essentially composed of the Tertiary formations, which is probably still being elevated, or, if not in elevation, is being denuded. On the other hand, the Kwanto plains, namely, the seismic district (II) and the vicinity of Tokyo, are composed partly of the diluvial and partly of the alluvial formations, which latter is steadily increasing in amount, and causing an ever increasing pressure on and about the Tokyo bay. Consequently it seems natural, apart from the process of horizontal crustal disturbances, that the hilly Tertiary district (I) is subject to an upward stress, while the Kwanto plains are subject to a steady downward pressure. In other words, the two regions under consideration are mutually opposite as regards the vertical tectonic disturbances at the seismic foci. The sharp initial vertical displacement at the origin directed upwards will correspond to the downward motion at the commencement of the earthquake motion at a place outside of the epicentral area, and *vice versa*.* The earthquakes accompanied by a loud A-type sound are probably caused by vertical tectonic disturbances, affecting a comparatively large area.

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* See the *Seismological Notes*, No. 2, page 20.

TOKYO OBSERVATION OF EARTHQUAKES ACCOMPANIED BY RUSHING SOUND.

p......Commencement of Preliminary Tremor.
s...... „ „ Principal Portion.

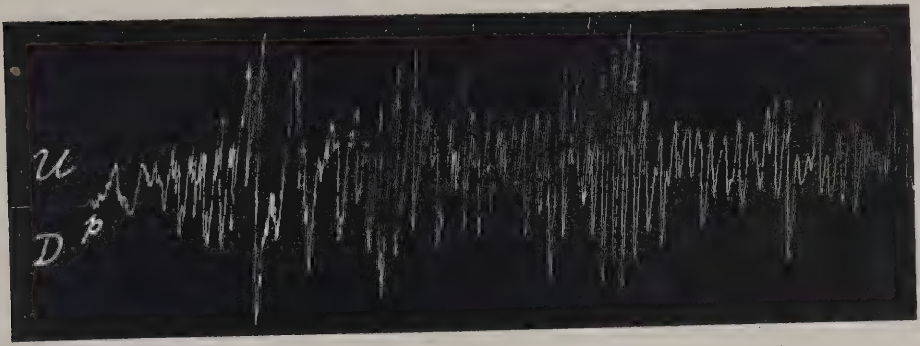


Fig. 36. Earthquake of Aug. 28, 1916, at 0.42.55 A.M. (Hongo.)
Magnification = 22. Time Scale: 1 min. = 26 mm.

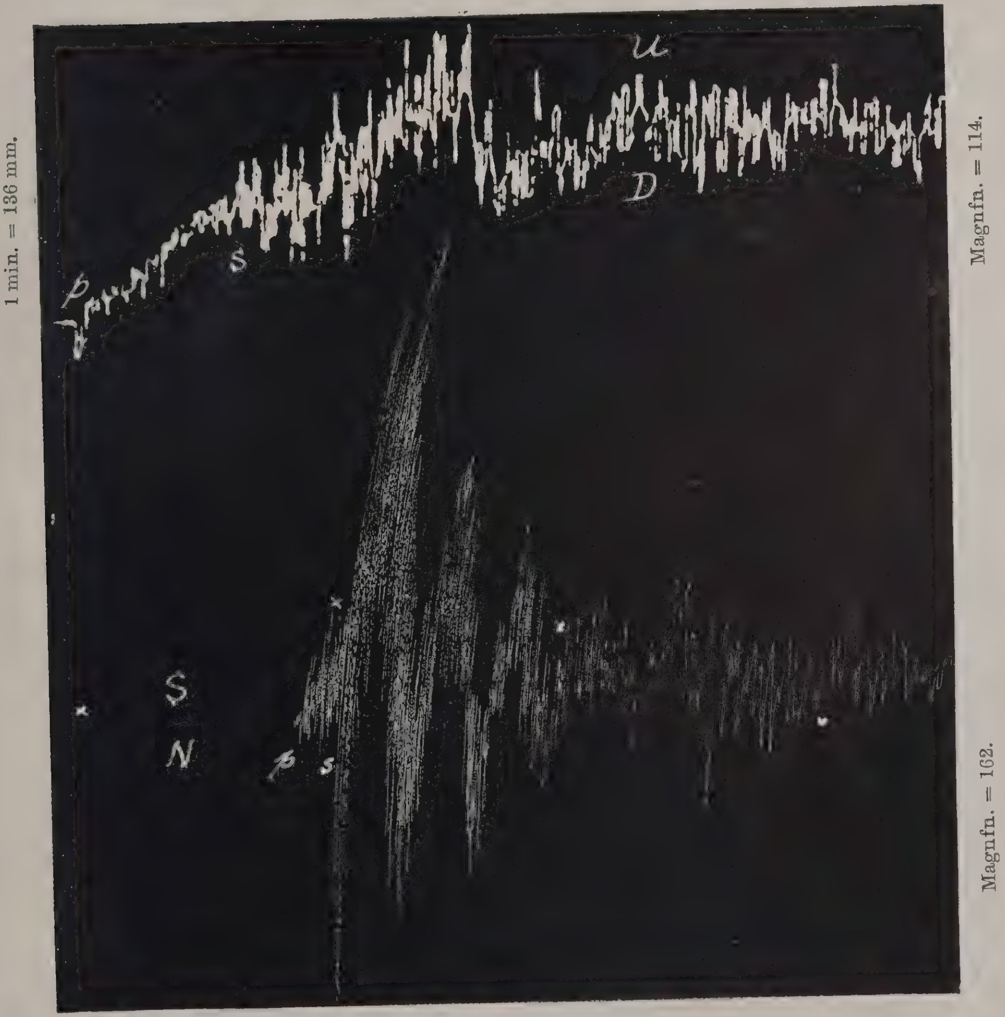


Fig. 37. Earthquake of Aug. 12, 1915, at 4.11.10 A.M. (Hongo.)
(×)......Successive Time (Minute) Cutting.

TOKYO OBSERVATION OF THE EARTHQUAKE OF AUG. 7, 1915, AT 10.45.12 A.M. ACCOMPANIED BY A RUSHING SOUND. (HONGO.)

t......Successive Time (Minute) Mark.

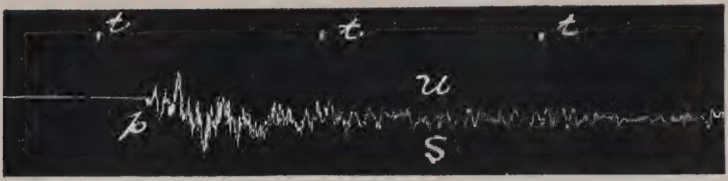
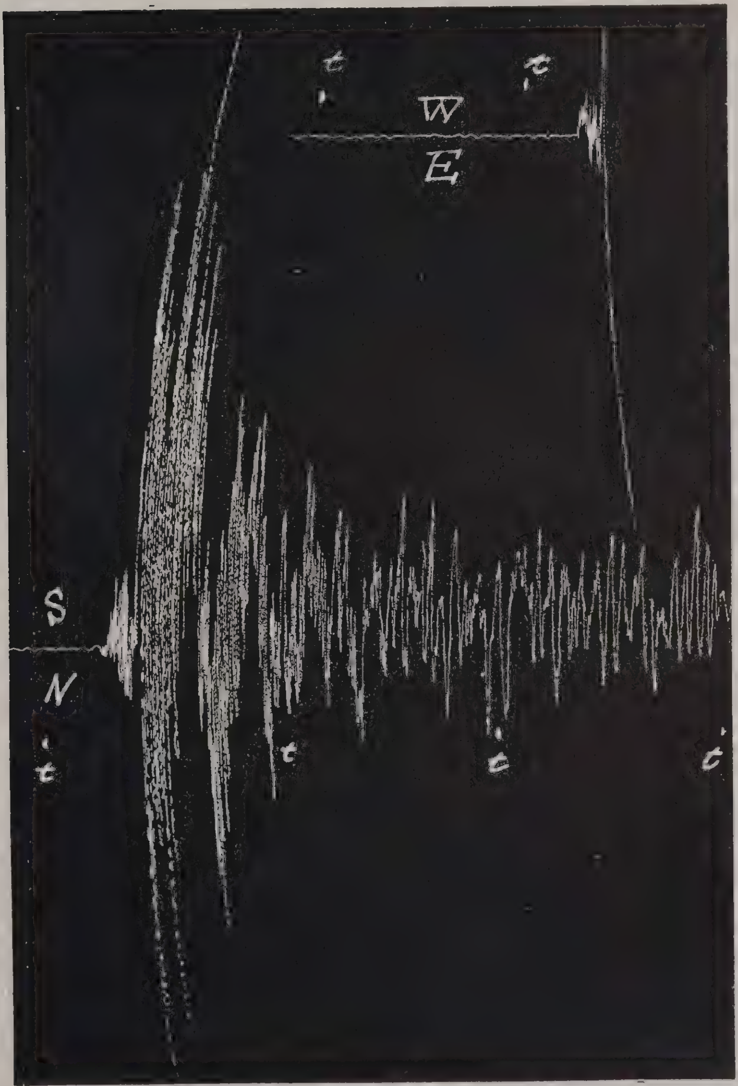


Fig. 38. Vertical Component. Magnification = 25.
p......Commencement of Preliminary Tremor.



Magnification = 149.

Magnification = 144.

Fig. 39. Horizontal Components.

CHOSHI OBSERVATION OF EARTHQUAKES WITH A WELL-DEFINED SHARP VERTICAL VIBRATION AT THE COMMENCEMENT.

p......Commencement.   t......Successive Time (Minute) Mark.

Vertical Component.   Magnification = 85.

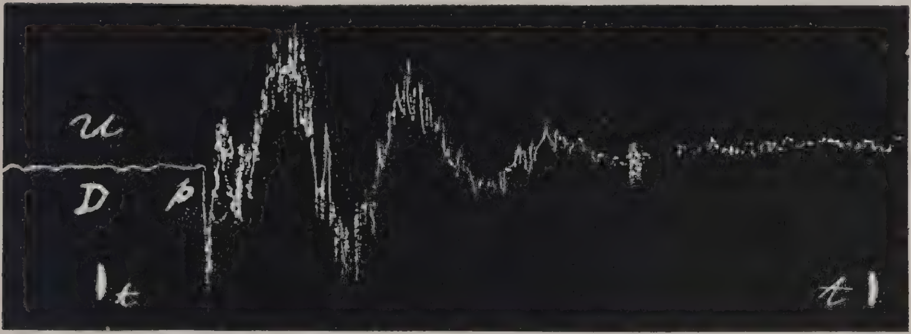


Fig. 40. Earthquake of July 10, 1919, at 1.24.19 A.M.

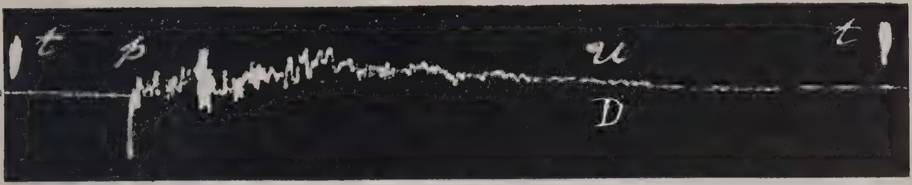


Fig. 41. Earthquake of July 10, 1919, at 1.47.26 A.M.

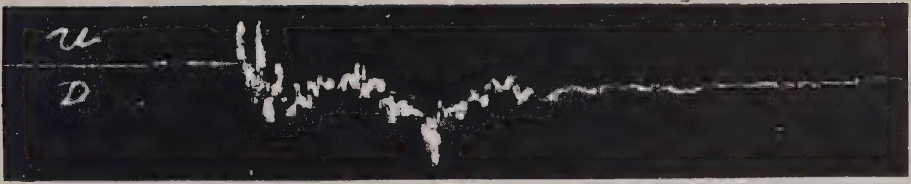


Fig. 42. Earthquake of July 30, 1918, at 3.00.35 A.M.
Time Scale: 1 Min. = 112 mm.

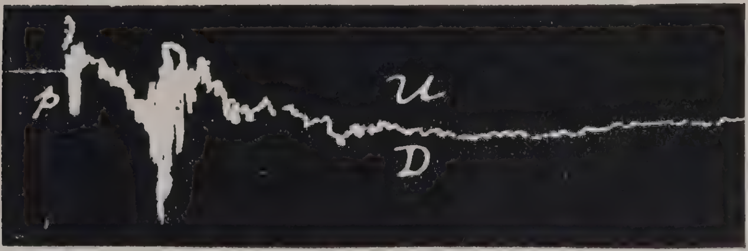
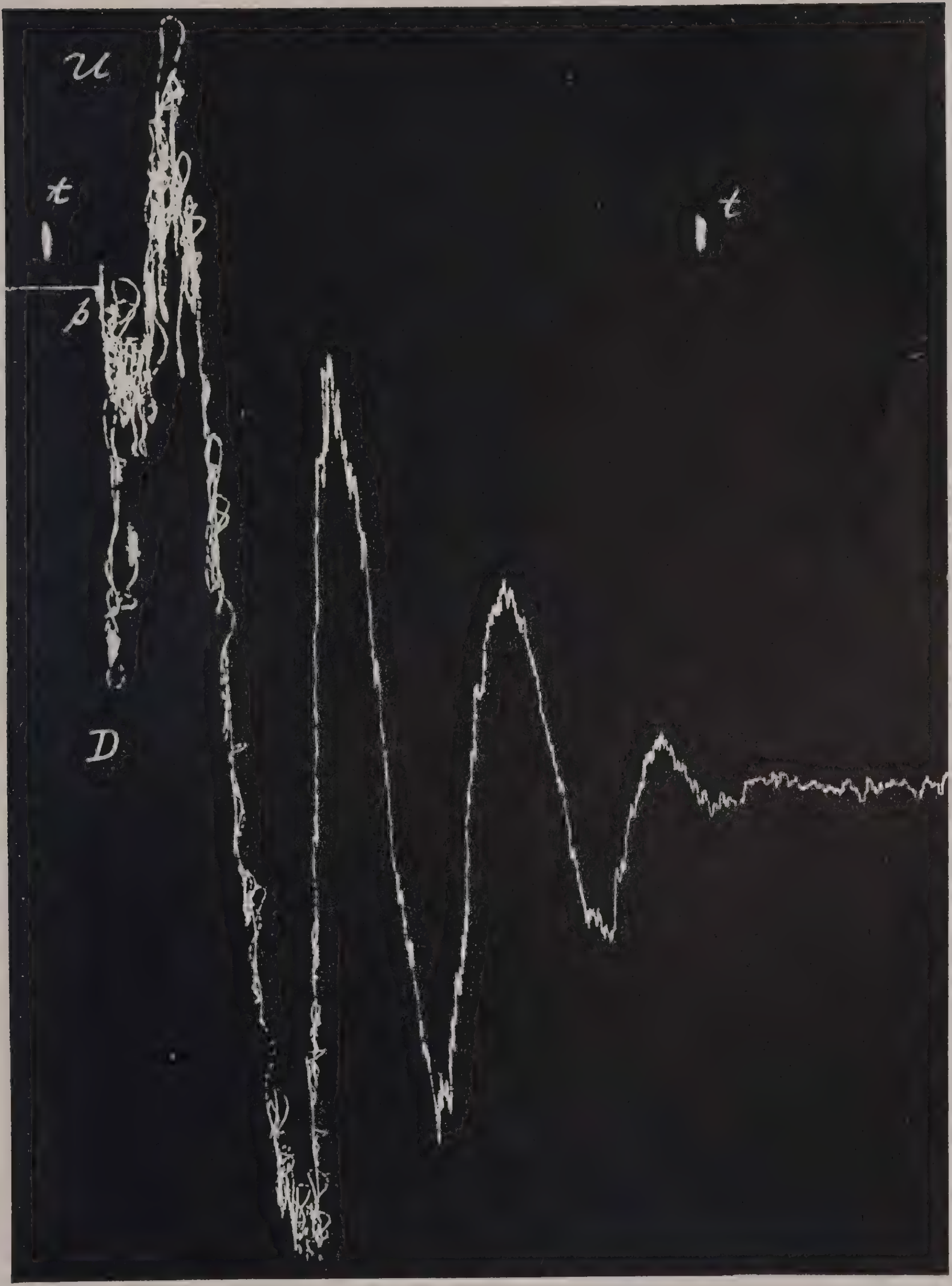


Fig. 43. Earthquake of June 9, 1919, at 8.14.51 A.M.
Time Scale: 1 Min. = 104.

Fig. 44. Choshi Observation of the Earthquake on July 10, 1919, at 1.20.43 A.M.: Vert. Component.



Magnification = 75. p......Commencement. t......Successive Time (Minute) Mark.

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A. IMAMURA and **K. HASEGAWA**: List of the After-shocks of the Great Kwanto Earthquake. 64–92

TOKYO

March, 1928

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A. Imamura and **K. Hasegawa**: List of the After-shocks of the Great Kwanto Earthquake. 64–92

TOKYO

March, 1928

List of the After-shocks of the Great Kwanto Earthquake.

By

A. Imamura and K. Hasegawa.

(*With Plates I-III.*)

In discussing the seismic activity of the Kwanto district,[1] one of the writers pointed out the primary necessity of distinguishing non-local destructive shocks from local destructive, or semi-destructive shocks. The distinguishing features of these shocks are as follows:—

> A non-local destructive shock is accompanied, as was the case in the great earthquake of Sept. 1, 1923, by a topographical change consisting of an upheaval or subsidence of as much as a few meters at the most in the whole of the Kwanto district, thus causing there an extraordinary loss of life and property.
>
> A local destructive or semi-destructive shock produces formidable effects only within a limited area—say, a circle with a radius of less than 15 km., as was the case of the destructive Yedo earthquake of 1855—the topographical changes produced being noticeable only by means of geodetic surveys.

The same writer further pointed out that the seismic activities in the Kwanto district were usually brought about by a non-local destructive earthquake which gave rise, for a number of years prior to its culmination, to many local destructive or semi-destructive shocks, besides causing slight and slow variations of land-level, until the cumulative activity suddenly reaches its culmination in a great earthquake, accompanied by sudden and extraordinary topographical changes with destruction on a vast scale. During the few years that follow adjustments for balance take place, causing many thousands of after-shocks until at last there arrives the dormant period of seismic activity which continues for a century or more. This might very well be called a cycle of seismic activity. Indeed the writer has recognized four such especially in the southeastern part, where the intensity rather surpassed that of the main shock.

---

[1] Imamura: Jap. Journal Astro. & Geoph., Vol. V, No. 3.

From the same table, it is clear that the after-shocks that occurred on the first day originated mostly in district A, whilst those originating in district B took place, for the most part, after the occurrence of no. 12, namely, the great earthquake of the next day. This correlation is more clearly shown in Table II, in which four-hourly numbers of the after-shocks are given. All these earthquakes are limited to those which could be felt by our unaided senses at Tokyo, the intensities represented by the Roman numerals III, II or I corresponding to earthquakes in which the double amplitude exceeded 3 mm., or was either greater than or less than 1 mm. respectively. The frequency of the shocks, or rather, earthquake sounds, which occurred in Tokyo and its environs attained its climax on the third day, but in general their occurrences were comparatively irregular.

The frequency variation in each district may be studied more closely from Table III, in which 24-hourly numbers are given, beginning at noon on Sept. 1. According to Mr. Yasuda, the numbers of earthquakes felt at Tokyo during October and the three months following were 96, 86, 139 and 167 respectively. The revival of seismic activity in the last two months was due to the occurrence of many minute local shocks in the northern part of Sagami in December, and to the after-shocks of the large earthquake of Jan. 15, 1924. Again, the number of shocks felt at Tokyo during the four months following the great earthquake and also in the years 1924–1927 were respectively 1044, 154, 68, 68 and 65. These figures are a striking contrast to the number 115, which is the yearly mean frequency during the period from 1888 to 1921,[5] a possible suggestion that the Kwanto district is now rapidly approaching its dormant period of seismic activity.

---

[5] Omori: Seismological Notes, No. 2.

TABLE I.

Tokyo observation of the great earthquake and its principal after-shocks.

No.	Date	Time of occurrence			Duration			Max. motion		Epicentre				Locality
					Prel. tr.	Princ. por.	Total	2a	T	λ		φ		
		h	m	s	s	m	m	mm	s	°	'	°	'	
1	IX 1	11	58	44	9.8	10	140	88.6	1.35	139	25	35	7	A
2	1	12	01	49	9.	<5		60.	2.0	139	28	35	10	A
3	1	12	17	47	12.0	1.5	> 5	4.8	2.4	139	02	35	02	A
4	1	12	24	00	7.2	1.2	7	48.0	1.2	139	19.0	35	25.0	A
5	1	12	30	20	6.5	0.2	1	8.5	0.5	140	0.0	35	50.0	C
6	1	12	36	43	7.4	0.5	2	7.5	2.0	140	05	35	54.0	C
7	1	12	40	20	9.1	3	> 8	39.4	2.0	139	31.7	35	03.8	A
8	1	12	48	03	13.3	3	>20	57.6	2.0	139	26.4	35	09.7	A
9	1	13	58	32	12.8	2.5	30	6.1	1.7	138	55.2	35	23.0	A
10	1	14	22	49	12.9	3	60	21.2	1.5	139	32.1	35	07.5	A
11	1	16	38	21	12.0	3	15	59.3	4.0	139	00.0	35	20.0	A
12	2	11	46	55	16.2	4	100	69.7	2.3	140	20.0	34	40.0	B
13	2	14	10	21	6.4	1	20	9.1	1.2	140	00.0	35	32.7	B
14	2	18	27	04	11.3	3	>20	57.6	2.6	140	32.0	35	27.6	B
15	2	18	49	02	12.0	3	20	9.1	2.3	140	37.5	35	23.8	B
16	2	22	09	29	17.0	2.5	30	45.5	4.6	139	42.2	35	07.0	A
17	2	23	16	46	12.3	2.2	20	9.1	1.5	139	27.5	35	14.1	A
18	26	17	24	03	16.0	3	80	26.0	2.3	139	28.3	34	40.7	A
19	X 4	0	54	29	11.1	1.3	30	10.2	0.8	139	04.6	35	18.6	A
20	5	22	05	46	9.3	3	30	3.7	0.8	139	07.3	35	24.6	A
21	XI 5	5	45	15	7.0	1	20	15.0	0.5	139	20.0	35	31.8	A
22	23	11	33	52	8.8	2	10	7.8	0.8	139	29.4	35	15.4	A
23	1924 I 15	5	50	24	10.2	4	60	59.0	1.8	139	16.6	35	26.2	A
24	VIII 6	23	22	49	11.6	3	40	7.8	3.2	140	37.5	35	40.3	B
25	IX 18	10	09	00	11.4	2	30	19.1	2.3	140	21.5	36	12.7	C
26	1926 VIII 3	18	26	22	7.6	0.5	30	28.3	1.6	139	48.5	35	34.3	D
27	1928 I 1	16	17	19	7.6	0.5	15	4.8	1.8	139	58.2	36	2.2	C
28	II 12	6	10	28	8.7	0.5	50	5.8	1.8	139	56.0	36	11.1	C

TABLE II.

Four-hourly numbers of after-shocks felt at Tokyo.

Locality		A				B				C				D			Total
Intensity	h h	III	II	I	III-I	III	II	I	III-I	III	II	I	III-I	II	I	II-I	
Sept. 1	12–16	23	36	56	115	0	0	0	0	2	2	2	6	2	8	10	131
	16–20	1	2	30	33	0	0	0	0	0	0	1	1	0	7	7	41
	20–24	1	0	13	14	0	0	1	1	0	0	0	0	0	1	1	16
Sept. 2	0–4	0	0	9	9	0	2	6	8	0	0	2	2	0	0	0	19
	4–8	0	0	8	8	0	3	6	9	0	0	1	1	0	0	0	18
	8–12	0	1	5	6	1	0	3	4	0	0	1	1	0	0	0	11
	12–16	0	0	6	6	1	1	10	12	0	0	0	0	0	0	0	18
	16–20	0	0	2	2	2	2	14	18	0	1	0	1	0	5	5	26
	20–24	2	0	2	4	0	0	7	7	0	0	2	2	0	2	2	15
Sept. 3	0–4	0	0	2	2	0	0	6	6	0	0	2	2	0	7	7	17
	4–8	0	0	2	2	0	0	6	6	0	0	0	0	0	3	3	11
	8–12	0	0	0	0	0	2	2	4	0	0	0	0	0	1	1	5
	12–16	0	0	4	4	0	0	0	0	0	0	1	1	0	12	12	17
	16–20	0	1	1	2	0	0	7	7	0	0	0	0	0	5	5	14
	20–24	0	1	2	3	0	0	4	4	0	0	0	0	0	4	4	11
Sept. 4	0–4	0	0	3	3	0	0	1	1	0	0	1	1	0	4	4	9
	4–8	0	0	1	1	0	0	2	2	0	0	0	0	0	7	7	10
	8–12	0	0	1	1	0	0	1	1	0	0	0	0	0	5	5	7
	12–16	0	0	0	0	0	0	1	1	1	0	1	2	0	2	2	5
	16–20	0	0	3	3	0	0	2	2	0	0	0	0	0	2	2	7
	20–24	0	0	2	2	0	0	3	3	0	0	2	2	0	1	1	8
Sept. 5	0–4	0	0	3	3	0	0	3	3	0	0	1	1	0	2	2	9
	4–8	0	0	1	1	0	0	2	2	0	1	0	1	0	1	1	5
	8–12	0	0	1	1	0	0	1	1	0	0	0	0	0	2	2	4
	12–16	0	0	1	1	0	0	2	2	0	0	0	0	0	1	1	4
	16–20	0	0	4	4	0	0	1	1	0	0	0	0	0	2	2	7
	20–24	0	0	1	1	0	0	3	3	0	0	0	0	0	2	2	6

Table III.

Daily numbers of after-shocks felt at Tokyo during the month following the great earthquake.

Type / Intensity / Date	A				B				C				D			Total
	I	II	III	I–III	I	II	III	I–III	I	II	III	I–III	I	II	I–II	
1	121	39	26	186	16	5	1	22	7	2	2	11	16	2	18	237
2	14	0	2	16	45	5	3	53	4	1	0	5	18	0	18	92
3	12	2	0	14	15	0	0	15	2	0	0	2	37	0	37	98
4	10	0	0	10	12	0	0	12	4	1	1	6	10	0	10	38
5	13	0	0	13	9	0	1	10	0	0	0	0	6	0	6	29
6	8	0	0	8	5	0	0	5	1	0	0	1	11	0	11	25
7	5	1	0	6	8	0	2	10	1	0	0	1	12	0	12	29
8	3	0	1	4	9	1	0	10	1	0	0	1	10	0	10	25
9	6	0	1	7	7	0	0	7	0	0	0	0	10	1	11	25
10	1	0	0	1	5	0	0	5	1	0	0	1	6	0	6	13
11	4	0	0	4	4	1	0	5	0	0	0	0	7	0	7	16
12	3	0	0	3	2	0	0	2	0	0	0	0	4	0	4	9
13	2	0	0	2	5	0	0	5	0	0	0	0	7	0	7	14
14	1	1	0	2	0	0	0	0	0	2	0	2	3	0	3	7
15	1	0	0	1	3	0	0	3	1	0	0	1	4	0	4	9
16	3	0	0	3	2	0	0	2	0	0	0	0	5	0	5	10
17	0	1	0	1	2	0	0	2	1	0	0	1	4	0	4	8
18	4	0	0	4	0	0	0	0	0	0	0	0	5	0	5	9
19	2	0	0	2	3	0	0	3	0	0	0	0	3	0	3	8
20	2	0	0	2	3	0	0	3	0	0	0	0	0	0	0	5
21	0	0	0	0	2	0	0	2	0	0	0	0	4	0	4	6
22	1	0	0	1	3	0	0	3	0	0	0	0	1	0	1	5
23	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
24	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	2
25	1	0	0	1	2	0	0	2	0	0	0	0	3	0	3	6
26	5	0	1	6	1	0	0	1	0	2	0	2	3	0	3	12
27	2	0	0	2	1	0	0	1	0	0	0	0	2	0	2	5
28	2	0	0	2	1	0	0	1	1	0	0	1	0	0	0	4
29	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1	2
30	1	0	0	1	4	0	0	4	0	0	0	0	0	0	0	5
Total	229	44	31	304	170	12	7	189	24	8	3	35	193	3	196	724

Date 1 covers 24 hours beginning at noon, Sept. 1, &c.

TABLE IV.

List of after-shocks felt at Tokyo during the month following the great earthquake.

No.	Time of occurrence			Duration			Max. range (2a)	Intensity	Type	Epicentre	Remark
				Prel. trem.	Princ. port.	Total					
						September 1.					
	h	m	s	s	m	m	mm				
1	11	53	44	9.8	10.0	140	88.6 (T=1.4s	III	A	$\lambda=139^\circ\ 25'$ $\varphi=\ 35^\circ\ 07'$	1
2	12	01	49	9.0?	>5.0		60. ? (T=2.0)	〃	〃	$\lambda=139^\circ\ 23'$ $\varphi=\ 35^\circ\ 10'$	2
3		03	10				50. ?	〃	〃		
4		04	16				—	II	〃		
5		04	43				—	〃	D		
6		05	52				2.8	〃	A		
7		06	12				—	〃	〃		
8		06	27				—	I	〃		
9		08	41				0.8	〃	D		
10		09	59				1.4?	II	A		
11		11	00				—	〃	〃		
12		11	39				1.2	〃	〃		
13		13	01				—	I	〃		
14		14	01				—	〃	〃		
15		14	25				0.7	〃	〃		
16		15	36		0.5		4.0	III	〃		3
17		16	49	6.9	0.3		4.0	〃	〃		4
18		17	16		0.2		4.0	〃	〃		5
19		17	34		0.2		2.0	II	〃		6
20		17	47	12.0	1.5	7.5	4.8 T=2.4)	III	〃	$\lambda=139^\circ\ 17'$ $\varphi=\ 35^\circ\ 02'$	7
21		18	14		0.4		5.8	〃	〃		8
22		18	37				6.0	〃	〃		
23		19	08				2.3	II	〃		9
24		19	47		0.1		1.5	〃	〃		10
25		20	07		0.3		1.8	〃	〃		11
26		21	26				2.6	〃	〃		12
27		22	07				1.8	〃	〃		14

Figures in the column of "Remark" indicate the earthquake numbers in Yasuda's list.

	h	m	s	s	m	m	mm				
28	12	22	33				1.6	II	A		15
29		23	21		0.8		2.0	〃	〃		17
30		24	00	7.2	1.2	7.0	48.0 (T=1.2)	III	〃	λ=139° 19′ φ= 35° 25′	19
31		26	49				—	I	〃		
32		27	04				—	〃	〃		
33		27	36				0.4	〃	〃		
34		29	39				4.0	III	〃		20
35		30	20	6.5	0.2	1.0	8.5 (T=0.5)	〃	C	λ=140° 00′ φ= 35° 50′	21
36		31	18	5.2			1.0	II	〃		
37		32	13				0.3	I	〃		
38		34	00		0.3	1.0	1.0	II	A		22
39		35	00		0.5	1.8	5.4	III	〃		23
40		36	48	7.4	0.5	2.0	7.5 (T=2.5)	〃	C	λ=140° 05′ φ= 35° 54′	24
41		37	32				0.3	I	A		
42		38	13		0.2		1.3	II	C		25
43		38	37				1.5	〃	A		26
44		39	15				0.8	I	〃		27
45		39	47				—	〃	C		28
46		40	01				-	〃	A		
47		40	07				—	〃	D		
48		40	20	9.1	3.0	8.0	39.4 (T=2.0)	III	A	λ=139° 31′.7 φ= 35° 3′.8	29
49		42	42				-	I	〃		
50		43	08				—	〃	〃		
51		43	47				—	〃	〃		
52		44	08				1.2	II	〃		
53		44	22				1.5	〃	〃		
54		47	00	7.6			—	I	〃		
55		47	18				—	〃	〃		
56		48	03	13.3	3.0	20	57.6 (T=2.0)	III	〃	λ=139° 26′.4 φ= 35° 9′.7	30
57		51	44	7.2			—	〃	〃		
58		52	27				—	II	〃		
59		54	11				—	I	〃		
60		55	12				—	〃	〃		
61		56	25	9.2			—	II	〃		
62		57	46				—	〃	〃		
63		59	26				-	I	〃		
64	13	01	49	14.0			1.1	II	〃		
65		02	37				-	〃	〃		32

No.	Time of occurrence	Duration			Max. range (2a)	Intensity	Type	Epicentre	Remark
		Prel. trem.	Princ. port.	Total					
	h m s	s	m	m	mm				
66	13 04 52	7.5			—	I	A		
67	05 32				0.2	〃	〃		
68	06 36				0.1	〃	〃		
69	07 03				0.3	〃	〃		
70	07 52				0.1	〃	〃		
71	08 45				0.1	〃	〃		
72	10 20				0.4	〃	〃		33
73	11 00				0.6	〃	〃		
74	11 31				1.8	II	〃		34
75	12 07	8.3			2.6	〃	〃		35
76	12 34				6.0	III	〃		36
77	13 23				5.5	〃	〃		37
78	14 10				7.2	〃	〃		
79	14 48				5.5	〃	〃		38
80	15 42				2.4	II	〃		
81	17 17				2.5	〃	〃		39
82	17 45				1.4	〃	〃		40
83	18 58				0.4	I	〃		41
84	19 33				0.2	〃	〃		42
85	20 11				0.1	〃	〃		43
86	21 29	8.7			1.0	II	〃		45
87	25 27				0.2	I	〃		47
88	27 04				0.2	〃	〃		48
89	28 10				0.3	〃	〃		50
90	29 07				0.2	〃	〃		51
91	31 12	12.1			3.0	III	〃		54
92	34 33	9.9			0.3	I	〃		55
93	36 17	9.9			1.1	II	〃		56
94	37 52				0.2	I	〃		
95	38 27	6.8			0.5	〃	〃		
96	44 07				0.2	〃	〃		60
97	45 33	9.3			0.4	〃	〃		61
98	49 48				1.2	II	〃		62
99	54 04				0.5	I	D		63

	h	m	s	s	m	m	mm				
100	13	58	32	12.8	2.5	30	6.1 (T=1.7)	III	A	$\lambda=140^\circ\ 20'.2$ $\varphi=\ 40^\circ\ \ 0'.5$	65
101	14	02	32				0.1	I	〃		
102		08	16				0.1	〃	〃		
103		12	33	10.6			0.3	〃	〃		68
104		15	38				0.1	〃	〃		
105		16	52				0.1	〃	D		
106		19	10	6.0			1.0	II	〃		69
107		22	49	12.9	3.0	60	21.2 (T=1.5)	III	A	$\lambda=139^\circ\ 32'.1$ $\varphi=\ 35^\circ\ \ 7'.5$	70
108		40	30				0.3	I	D		72
109		45	17				0.2	〃	〃		
110		46	03				0.8	〃	A		73
111		50	34				0.3	〃	〃		74
112		53	51				0.3	〃	〃		77
113		58	02		0.2	2.0	0.9	〃	D		78
114	15	00	26				0.1	〃	A		
115		02	22				0.2	〃	〃		80
116		02	57				0.2	〃	〃		81
117		04	13				0.1	〃	〃		
118		04	35				6.0	III	〃		82
119		15	05				2.7	II	〃		88
120		19	14	11.5		5.0	9.5	III	〃		91
121		22	17				0.2	I	〃		
122		22	38				0.2	〃	〃		
123		23	24				0.1	〃	〃		
124		26	27		0.4		1.5	II	〃		93
125		29	11				1.1	〃	〃		96
126		33	18				0.1	I	〃		97
127		36	54				0.2	〃	〃		98
128		39	35				0.1	〃	〃		99
129		40	48				0.6	〃	〃		101
130		43	55		0.7		2.5	II	〃		104
131		52	36				0.1	I	D		
132		56	39		0.4		2.1	II	A		106
133	16	02	38				0.1	I	〃		
134		05	41				0.1	〃	〃		110
135		07	15			1.0	0.3	〃	〃		
136		09	46				0.1	〃	〃		

No.	Time of occurrence			Duration			Max. range (2a)	Intensity	Type	Epicentre	Remark
				Prel. trem.	Princ. port.	Total					
	h	m	s	s	m	m	mm				
137	16	17	13				0.1	I	A		
138		23	25		0.3	3.0	1.1	II	〃		113
139		38	21	12.0	3.0	15	59.3 (T=4.0)	III	〃	λ=139° 00′ φ= 35° 20′	114
140		46	45				—	I	〃		
141		57	13			0.5	0.1	〃	〃		
142	17	01	08				0.1	〃	〃		
143		04	20				0.4	〃	D		
144		11	19				0.5	〃	A		117
145		13	55				0.7	〃	D		
146		20	43				0.1	〃	A		
147		32	56				—	〃	〃		119
148		34	21				0.2	〃	〃		120
149		38	41				0.1	〃	D		
150		39	02				0.1	〃	A		
151		47	24				0.1	〃	〃		
152		50	11				—	〃	〃		
153		52	28	10.6		1.5	0.1	〃	D		124
154		59	32				0.1	〃	A		127
155	18	00	22				0.2	〃	〃		128
156		01	01				0.2	〃	〃		129
157		13	36			1.2	0.2	〃	〃		133
158		18	53				0.1	〃	D		136
159		20	33				0.2	〃	〃		137
160		23	26				0.2	〃	A		138
161		31	40				0.2	〃	〃		140
162		42	24				0.1	〃	〃		145
163		46	08				—	〃	〃		
164		49	14				—	〃	〃		
165		54	03				0.1	〃	〃		150
166	19	00	41		1.3		0.2	〃	〃		153
167		04	18			1.0	0.3	〃	〃		155
168		05	57				0.2	〃	〃		156
169		16	36				0.1	〃	D		158
170		21	59				0.1	〃	A		159

	h	m	s	s	m	m	mm				
171	19	25	36	7.3	4.0	2.0	2.6	II	A		160
172		46	31				0.1	I	〃		162
173		55	36				0.2	〃	C		164
174	20	00	56				0.2	〃	A		
175		38	18				0.3	〃	D		
176		39	54	8.2		1.0	0.4	〃	A		172
177		41	22				0.2	〃	〃		173
178		52	09		0.3	1.2	0.2	〃	〃		177
179	21	05	08				0.1	〃	〃		
180		19	54		0.2	1.1	0.9	〃	B		182
181		46	08				0.1	〃	A		188
182		47	22				0.1	〃	〃		189
183		57	46				0.1	〃	〃		194
184	22	17	59				—	〃	〃		197
185		32	19			2.0	0.3	〃	〃		199
186		52	34	16.2	2.0	5.0	7.4 (T=3.0)	III	〃	Uraga Channel	207
187	23	07	04				—	I	〃		
188		25	26				0.1	〃	〃		218
189		37	25				0.2	〃	〃		220

September 2.

	h	m	s	s	m	m	mm				
190	00	00	51				—	I	A		226
191		05	48			2.0	0.1	〃	〃		229
192		11	54			3.0	0.1	〃	〃		230
193		34	54				0.1	〃	〃		
194		41	26	10.0	1.0	7.0	0.9	〃	B		233
195	01	11	59	9.0	2.0	1.0	0.4	〃	A		239
196		15	47				0.1	〃	C		240
197		17	08				0.1	〃	〃		
198		35	46				0.1	〃	A		
199		59	37	8.0	0.2	2.0	2.8 (T=2.0)	II	B	$\begin{cases}\lambda=140° \ 05'\\ \varphi= \ 35° \ 17'\end{cases}$	248
200	02	02	23	11.0	1.0	4.0	2.4 (T=2.2)	〃	〃	Off Kamogawa	250
201		13	48	13.0	0.7	3.0	0.8	I	〃	Off Kuzyukuri-hama	257
202		24	11		0.3	1.3	0.3	〃	A		260
203		33	40			0.2	0.3	〃	B		261
204		59	25				—	〃	A		
205		59	54	12.2		1.3	0.3	〃	〃		265
206	03	35	25	9.1			0.1	〃	B		267

No.	Time of occurrence			Duration			Max. range (2a)	Intensity	Type	Epicentre	Remark
				Prel. trem.	Princ. port.	Total					
	h	m	s	s	m	m	mm				
207	03	42	10				0.3	I	B		
208		43	33				0.7	〃	〃		272
209	04	08	39	9.0	0.5	5.0	2.7	II	〃	N. Kadusa	273
210		13	50				0.5	I	A		274
211		18	16				0.6	〃	〃		281
212		20	43		0.7	2.0	0.2	〃	B		282
213		43	45				—	〃	A		
214	05	10	20				0.2	〃	〃		288
215		14	40	9.5	0.2		0.2	〃	B		289
216		18	45				0 3	〃	C		292
217	06	09	00				0 4	〃	A		297
218		12	10		0.8	2.0	0.6	〃	〃		298
219		17	09				0.4	〃	B		300
220		31	17				0.1	〃	〃		301
221		43	40	9.7	0.5		1.6	II	〃		305
222	07	06	19		0.3	1.7	0.5	I	A		309
223		11	29	8.0	1.0		0.1	〃	B		313
224		12	52		0.3		0.5	〃	〃		314
225		16	57				0.1	〃	A		316
226		50	34	6.4	0.5	6.0	2.9	II	B	N. Kaduza	319
227	08	00	37		0.6	2.0	0.3	I	A		322
228	09	08	45				0.1	〃	〃		328
229		34	06				0.1	〃	B		
230	10	00	02	9.1	1.0	7.0	1.0	II	A	Off Kisaradu	333
231		13	35				0.2	I	〃		340
232		17	47				—	〃	〃		
233	11	05	00	7.0	0.5	1.0	0.9 (T=2.2)	〃	C		352
234		17	50				—	〃	A		
235		36	30				—	〃	B		
236		46	55	16.2	4.0	100	69.7 (T=2.3)	III	〃	{λ=140° 20′ φ= 34° 45′	353
237		54	41		0.7		0.9	I	〃		354
238	12	07	12				0.2	〃	A		367
239		26	17				0.1	〃	B		
240		32	17	11.0	0.6		0.2	〃	〃		378

	h	m	s	s	m	m	mm				
241	12	38	13				0.1	I	B		
242		52	25				0.2	〃	〃		
243	13	04	50				0.2	〃	〃		381
244		11	50				0.2	〃	〃		383
245		37	54				0.2	〃	A		385
246		48	11	7.4	2.0	10	2.6	II	B		394
247	14	05	47	7.5	1.0	5.0	0.7	I	A	Central Sagami	396
248		09	60				—	〃	〃		
249		10	21	6.4	1.0	4.0	10.6 (T=1.2)	III	B	λ=140° 00′.0 φ= 35° 32′.7	397
250		23	59	6.0			0.2	I	〃		398
251		30	23				—	〃	〃		
252		49	20	6,9	1.0		0.1	〃	A		404
253	15	02	31	9.3	0.3	1.0	0.2	〃	〃		406
254		18	44				0.1	〃	B		
255		32	44	11.8	0.3	1.5	0.6	〃	〃	W. Awa	408
256	16	18	05				0.1	〃	D		
257		22	45		0.6		0.1	〃	〃		
258		29	04	7.0	0.3	2.0	1.8	II	C	N. Kadusa	412
259		50	53				0.1	I	D		
260		52	01	8.9			0.1	〃	B		
261	17	23	01				0.1	〃	〃		414
262		49	00	9.9	0.5		0.1	〃	〃		415
263		52	14	3.7 ?			0.4	〃	D		416
264	18	27	04	11.3	3.0	2.0	57.6 (T=2.6)	III	B	λ=140° 32′.0 φ= 35° 27′.6	417
265		33	11				2.2	II	〃		
266		36	45				0·3	I	〃		418
267		45	13				0.1	〃	〃		419
268		46	45				0.2	〃	〃		420
269		49	02	12.0	3.0	20	.91 (T=2.3)	III	〃	λ=140° 37′.5 φ= 35° 23′.8	421
270		59	34				0.1	I	A		423
271	19	01	53				0.1	〃	B		424
272		07	39				0.1	〃	〃		427
273		11	38				0.1	〃	〃		
274		13	03	6.5	0.5		0.5	〃	D		429
275		23	53		1.0		1.1	II	B		431
276		33	19				0.1	I	〃		
277		40	45				0.1	〃	〃		
278		42	30				0.2	〃	〃		440

No.	Time of occurrence			Duration			Max. range (2a)	Intensity	Type	Epcientre	Remark
				Prel. trem.	Princ. port.	Total					
	h	m	s	s	m	m	mm				
279	19	46	25				0.1	I	B		
280		51	40				0.1	〃	A		
281		59	11	7.0		1.5	0.2	〃	B		443
282	20	02	17				0.1	〃	〃		444
283		04	31				0.1	〃	A		445
284		11	43				0.3	〃	B		446
285		17	29		0.8		0.1	〃	D		
286		43	51	10.2		2.0	0.4	〃	B		451
287		46	51				0.1	〃	D		
288	21	08	07		0.8		0.2	〃	C		454
289		25	16				0.1	〃	B		
290		27	33				0.1	〃	〃		459
291		31	22				0.2	〃	C		460
292		36	54				0.2	〃	A		461
293	22	09	29	17.0	2.5	30	45.4 (T=4.6)	III	〃	$\lambda=139^\circ\ 42'.2$ $\varphi=35^\circ\ 7'.0$	463
294		53	44		0.5		0.3	I	B		466
295	23	16	46	12.3	2.2	20	9.1 T=1.5)	III	A	$\lambda=139^\circ\ 27'.5$ $\varphi=35^\circ\ 14'.1$	467
296		49	21				0.1	I	B		
September 3.											
297	00	12	20				0.1	I	D		471
298		37	06				0.2	〃	B		472
299		51	50	8.9			0.2	〃	C		473
300	01	07	21		0.6		0.2	〃	B		474
301		36	29		0.4	1.5	0.2	〃	D		476
302		58	41				0.1	〃	〃		
303		59	56				0.1	〃	B		
304	02	13	35		0.3		0.2	〃	D		477
305		15	43	8.2	1.6		0.3	〃	B		478
306		27	53				0.1	〃	C		
307		42	53		0.4		0.1	〃	B		479
308	03	08	03				0.1	〃	D		480
309		16	21				0.1	〃	〃		
310		21	45		0.5		0.2	〃	〃		481

	h	m	s	s	m	m	mm				
311	03	22	41				0.2	I	B		482
312		38	13			6.0	0.1	〃	A		483
313		57	43			2.0	0.2	〃	〃		484 Vol. type
314	04	33	49		0.2		0.2	〃	D		485
315	05	00	37				0.1	〃	B		486
316		35	50				0.1	〃	D		
317	06	01	56	12.3	2.0	7.0	0.4	〃	B	Kuzyukurihama	487
318		16	37				0.1	〃	〃		
319		29	41				0.1	〃	〃		
320		38	09		1.1		0.4	〃	〃		
321		44	39		0.3		0.1	〃	〃		
322		59	51				0.1	〃	D		
323	07	21	15				0.1	〃	A		
324		50	39		1.2		0.2	〃	〃		
325	09	09	39	9.5	2.5	14	1.2	II	B	E. Kadusa	492
326		26	24				0.1	I	D		
327		40	23	10.0	2.0	12	0.4	〃	B	E. Awa	493
328	10	47	14	5.0	2.0	13	1.7	II	〃	S. Simôsa	495
329	11	55	50				0.1	I	〃		496
330	12	22	04				0.1	〃	D		
331		26	54				0.1	〃	A		
332		35	04		0.4		0.2	〃	D		502
333	13	47	53				0.1	〃	A		
334		52	16				0.1	〃	D		
335		52	57				0.1	〃	〃		505
336		53	59				0.1	〃	〃		
337	14	00	50				0.1	〃	〃		
338		03	57		0.4		0.4	〃	〃		507
339		09	59				0.1	〃	〃		
340		21	18	18.1	2.0	15	0.8	〃	A	S.E. of Oosima	509
341		53	46	7.3	0.3	4.0	0.6	〃	D	W. Simôsa	513
342	15	02	19	6.5	0.8	4.0	0.4	〃	C	〃	517
343		15	19				0.1	〃	D		
344		31	08				0.1	〃	〃		
345		44	54		0.2	2.0	0.2	〃	A		522
346		49	01				0.1	〃	D		
347	16	10	09		0.2		0.1	〃	A		
348		12	35		0.2		0.1	〃	B		528

No.	Time of occurrence			Duration			Max. range (2a)	Intensity	Type	Epicentre	Remark
				Prel. trem.	Princ. port.	Total					
	h	m	s	s	m	m	mm				
349	16	27	19				0.1	I	D		
350		40	12				0.1	〃	〃		532
351	17	14	01	6.3	0.6		1.6	II	A	Off Yokosuka	533
352		35	52				0.1	I	D		
353		38	51	8.0	0.4	4.0	0.2	〃	B	N. Kadusa	535
354		53	13		0.3		0.2	〃	〃		537
355	18	20	57	6.5	0.3	1.0	0.4	〃	〃	E. Kadusa	538
356		23	53	7.8	0.5	1.5	0.3	〃	〃		539
357		29	25		0.4		0.1	〃	〃		542
358		36	13		0.3		0.1	〃	D		
359	19	10	38				0.1	〃	B		
360		43	55		0.2		0.1	〃	D		549
361	21	21	32	7.5			0.2	〃	B		550
362		49	32				0.1	〃	D		
363		59	46				0.1	〃	B		
364	22	02	28		0.2		0.1	〃	〃		553
365		17	18				0.1	〃	D		
366		29	04	5.7	0.8	5.0	0.9	〃	A	S.W. Musasi	554
367	23	00	02	10.0			0.1	〃	〃		556
368		11	32				0.2	〃	D		
369		30	47	10.1	0.2	4.0	2.5 (T=1.1)	II	A	W. Sagami	560
370		46	22				0.1	I	D		564
371		52	12	7.5	0.7	5.0	0.9	〃	B	W. coast of Kadusa	565
September 4											
372	00	47	05				0.1	I	D		569
373		52	37				0.1	〃	B		570
374		54	11				—	〃	A		571
375	01	35	32				0.1	〃	D		
376		58	47				0.1	〃	C		574
377	02	08	05				—	〃	A		
378		16	45				—	〃	D		
379		45	52				0.1	〃	〃		575
380		46	17				—	〃	A		576

	h	m	s	s	m	m	mm				
381	04	05	34				0.1	I	D		577
382		08	33		0.3		0.3	〃	〃		578
383		24	38				—	〃	〃		
384		53	36		0.1		0.1	〃	〃		
385	05	35	43				—	〃	〃		
386		51	33				—	〃	〃		
387	06	22	53	7.3	0.5	5.0	0.7	〃	B	Central Kadusa	580
388		32	32	9.6	0.3	2.5	0.2	〃	A		581
389	07	44	14				—	〃	D		
390		49	13				—	〃	B		
391	08	09	37				—	〃	D		
392		21	28				0.1	〃	〃		
393		47	21				0.1	〃	〃		
394	09	59	04	8.2			0.3	〃	B		
395	11	11	50					〃	D		
396		38	11	13.4		2.5	0.1	〃	A		586
397		41	37				0.1	〃	D		587
398	12	33	53				0.1	〃	〃		
399	13	00	52	17.4	4.0	20	3.1	III	C	λ=142° 4′.9 φ= 36° 00′.0	589
400		58	50				0.1	I	D		597
401	14	57	30	22.0	3.0	15	0.4	〃	C	λ=141° 41′.6 φ= 36° 8′.1	599
402	15	48	13	5.4	0.8	6.0	0.6	〃	B	Near Kisaradu	603
403	16	37	53	13.3		0.2	0.1	〃	A		609
404	17	30	26				—	〃	D		
405	18	05	04			1.0	0.3	〃	A		612
406		50	13		0.4	1.2	0.1	〃	〃		615
407	19	04	10		0.2		0.1	〃	B		616
408		11	09	7.2	0.5	7.0	0.3	〃	〃	Central Simôsa	617
409		32	21				0.1	〃	D		
410	20	45	52	7.5	0.5	3.0	0.3	〃	A	Central Sagami	626
411	21	06	28		0.3		0.1	〃	C		629
412	22	42	08				—	〃	A		644
413		45	36		0.1		0.1	〃	D		645
414		51	37	6.0	0.4	2.0	0.6	〃	C	Central Kadusa	646
415	23	02	31				0.1	〃	B		
416		29	24		0.3		0.2	〃	〃		647
417		39	24		0.3		0.2	〃	〃		648

No.	Time of occurrence	Duration			Max. range (2a)	Intensity	Type	Epicentre	Remark
		Prel. trem.	Princ. port.	Total					
September 5									
	h m s	s	m	m	mm				
418	00 25 03	7.6		1.4	0.3	I	A		649
419	42 01	9.7	0.8	5.0	0.3	〃	B	S.W. Kasumigaura	650
420	01 16 33		0.3	1.0	0.1	〃	C		653
421	02 02 40	6.2	0.4	3.0	0.7	〃	D	Central Musasi	655
422	26 25		0.4	3.0	0.1	〃	A		656
423	41 40			1.5	0.4	〃	〃		660
424	03 14 37				0.1	〃	D		
425	16 06	5.0	1.2	5.0	0.6	〃	B	Near Kisaradu	663
426	22 10		0.5		0.1	〃	〃		664
427	05 17 22				0.1	〃	D		
428	24 37	6.5	0.6		0.2	〃	B		665
429	34 15				0.1	〃	A		666
430	07 20 18		0.2		0.1	〃	B		667
431	23 07	23.3	4.0	25	2.3	II	C	Near Ootawara	668
432	09 18 16				0.1	I	D		
433	23 29	14.9			0.1	〃	A		
434	10 09 43				0.1	〃	B		
435	11 46 39				0.1	〃	D		
436	12 11 43				0.1	〃	〃		
437	42 16		0.4		0.1	〃	B		692
438	14 25 15		0.2		0.1	〃	A		698
439	15 27 49				0.1	〃	B		
440	16 00 09				0.1	〃	A		
441	13 57				—	〃	〃		
442	52 38		0.2		0.1	〃	〃		705
443	17 06 31	6.1	0.2	1.0	0.4	〃	D	W. Kadusa	707
444	18 34 37	12.2	2.0	15	0.4	〃	B	S.W. of Katuura	709
445	19 23 45				0.1	〃	D		713
446	51 36		0.2		0.1	〃	A		714
447	20 13 02	13.7	1.5	15	0.9	〃	B	Off Kasima	715
448	21 17 31				—	〃	D		
449	22 42 59			1.5	0.1	〃	B		719

	h	m	s	s	m	m	mm				
450	22	51	54				0.1	I	A		
451	23	28	13				0.1	〃	B		720
452		33	53				—	〃	D		

September 6

453	00	40	36	8.4	0.5	5.0	0.2	I	B	Central Kadusa	722
454	01	46	49				—	〃	A		731
455	02	10	27	11.8	0.2	1.2	0.1	〃	〃		734
456	03	29	55	9.8	4.0	15	4.5 (T=2.0)	III	B	Near Sawara	744
457		46	33	9.0	0.9	15	0.5	I	〃		746
458	04	26	57		0.3		0.1	〃	〃		747
459	05	00	18	6.6	5.5	50	0.4	〃	A		749
460	06	03	08		0.2		0.1	〃	〃		750
461		45	56		2.0	20	0.4 (T=2.9)	〃	〃		751 Vol. type
462	07	45	21	23.6	0.6		0.1	〃	〃	Suruga	
463	10	42	01				0.1	〃	D		752
464		50	51				0.1	〃	A		
465	12	23	59					〃	〃		
466	13	18	24	7.5			0.1	〃	〃		
467	15	03	52				0.1	〃	〃		
468	18	02	56	9.8	0.3	5.0	0.2	〃	〃	Central Sagami	767
469		41	46	7.2	0.2		0.1	〃	〃		768
470	20	14	42	8.4	0.8	3.0	0.1	〃	B	Central Kadusa	770
471		36	55	10.8	0.8	10	0.1	〃	〃	E. Kadusa	772
472		47	16				0.1	〃	D		774
473		57	24		0.3		0.2	〃	〃		777
474	22	34	46				0.1	〃	C		
475	23	39	01				—	〃	A		

September 7

476	00	06	08				—	I	D		
477		13	53				0.1	〃	A		782
478	01	05	45		0.2		0.1	〃	B		783
479		50	10				0.1	〃	〃		
480	03	28	11	9.3	0.8	5.0	0.1	〃	A	Uraga Channel	784
481	04	45	17	10.8	0.4	3.0	0.2	〃	B	S.E. Kadusa	785
482	05	50	34				0.1	〃	D		786
483	06	51	17				0.1	〃	〃		

No.	Time of occurrence			Duration			Max. range (2a)	Intensity	Type	Epicentre	Remark
				Prel. trem.	Princ. port.	Total					
	h	m	s	s	m	m	mm				
484	08	03	05				0.1	I	D		
485		09	27				0.1	〃	〃		
486		45	38				0.1	〃	〃		
487	10	38	53				0.1	〃	〃		789
488	11	18	23	4.7	0.1		0.2	〃	〃		791
489		18	35		0.1		0.2	〃	〃		
490	12	59	14			2.0	0.1	〃	A		796
491	13	60	18				0.1	〃	D		798
492	15	50	41		0.2		0.1	〃	B		811
493	16	31	17				0.1	〃	D		822
494	17	55	05		0.2		0.1	〃	B		828
495	18	18	23				—	〃	D		830
496	19	01	15				0.1	〃	〃		831
497	20	31	32	11.7	2.0	15	0.3	〃	A	Uraga Channel	832
498	21	40	59				0.1	〃	C		
499	22	43	42	11.1	1.0	7.0	0.3	〃	A	N.E. Awa	835
500	23	30	26	9.3	2.0	10	1.4	II	〃	Off Yokosuka	837
501		46	46	7.4	0.8	3.0	0.5	I	B	N.E. Kadusa	838
502		52	13		0.1		0.2	〃	D		839
503		58	02				—	〃	〃		
September 8											
504	00	17	12	9.7	2.0	15	4.8	III	B	N.E. Kadusa	840
505		22	48				0.2	I	〃		842
506		37	30				—	〃	D		
507		52	12				0.1	〃	〃		844
508		52	50				—	〃	〃		
509	02	06	20	9.6	0.3	1.5	0.1	〃	A		845
510		32	50	12.2	6.0	40	9.9 (T=1.3)	III	B	Off S. Awa	846
511		55	39				—	I	〃		
512	06	39	07				0.1	〃	D		
513	08	39	40	10.8	2.0	10	0.9 (T=1.1)	〃	B	Off Kuzyukurihama	857
514		42	46				0.1	〃	D		
515		51	44				0.1	〃	B		

	h	m	s	s	m	m	mm				
516	10	38	10				0.1	I	A		869
517	11	28	05					〃	D		874
518		32	57			0.5	0.1	〃	B		875
519	12	43	01	8.3	0.3	2.0	0.1	〃	〃	W. Kadusa	882
520		55	26		0.1		0.2	〃	D		884
521	13	07	40	10.5	1.5	7.0	0.2	〃	B	Off Katuura	883
522		46	02	12.7	2.0	10	0.4	〃	〃	Off Katuura	891
523	15	34	14				0.1	〃	D		901
524	17	56	36	6.4	0.4	3.0	0.1	〃	C	W. Simôsa	917
525	18	08	54	12.2	4.0	20	3.7	III	A	N.W. Musasi	918
526		26	16				0.1	I	〃		919
527	19	39	43					〃	D		
528	20	46	09	12.0	1.0	6.0	0.2	〃	B	Off E. Awa	920
529	21	24	16				0.1	〃	D		
530	22	41	25				—	〃	〃		921
531		53	37		0.2		0.1	〃	B		922

September 9

532	00	14	51		0.2		0.1	I	D		923
533		15	16		0.2		0.1	〃	〃		
534	01	22	14				0.1	〃	〃		
535		46	11		0.2		0.1	〃	B		924
536		50	47	6.4	0.3	15	0.2	〃	〃	N.W. Kadusa	925
537	03	17	19				—	〃	D		928
538	04	11	27	15.6	3.0	15	1.4	II	B	Off S.E. coast of Bôsô Pen.	930
539		40	41	11.3	0.6	4.0	0.2	I	〃	Off Kuzyukurihama	933
540	05	57	18		0.3		0.3	〃	A		937
541	06	25	41				0.1	〃	D		
542	08	24	30				—	〃	A		
543	11	48	37				—	〃	B		
544	12	03	07	8.0	1.5	7.0	0.4	〃	〃	N.E. Kadusa	949
545		21	29	7.7	0.3	2.0	0.3	〃	D		950
546	14	28	26		0.1		0.1	〃	〃		
547	15	09	46		0.1		—	〃	〃		
548		22	44	6.4	0.2	2.0	0.1	〃	B	Central Kadusa	963
549		51	49	5.5	1.0	5.0	2.4	II	D	W. Kadusa	966
550	16	51	25		0.3		0.3	I	〃		979
551	17	20	35		0.4		0.1	〃	B		982

No.	Time of occurrence			Duration			Max. range (2a)	Intensity	Type	Epicentre	Remark
				Prel. trem.	Princ. port.	Total					
	h	m	s	s	m	m	mm				
552	20	26	55				—	I	D		
553	21	56	33				0.1	〃	〃		986
554	22	52	58		0.1		0.1	〃	B		
555	23	12	20	11.5			0.1	〃	A		

September 10

No.	h	m	s	Prel. trem.	Princ. port.	Total	Max. range (2a)	Intensity	Type	Epicentre	Remark
556	02	07	46	9.8			0.6	I	A		991
557		11	06	15.6	5.0	30	3.2 (T=1.2)	III	〃		992
558	03	02	13				0.1	I	〃		999
559	04	04	59				—	〃	D		1002
560		54	44				—	〃	〃		
561	06	16	47	11.0			0.1	〃	B		1005
562	07	18	37				0.2	〃	〃		
563	08	36	36				—	〃	D		
564		39	30				—	〃	〃		
565	09	14	23		0.2		0.1	〃	B		
566		49	36				—	〃	A		
567	11	05	51				—	〃	〃		
568		27	23				0.1	〃	〃		1013 Vol. typ
569	12	41	50				0.1	〃	B		
570	13	00	45		0.2		0.1	〃	D		1019
571	15	06	36				0.1	〃	A		
572	16	11	33		0.2		0.1	〃	B		1022
573	17	42	16				—	〃	〃		1023
574	19	28	41				—	〃	D		1026
575	21	42	54				0.1	〃	〃		1028

September 11

No.	h	m	s	Prel. trem.	Princ. port.	Total	Max. range (2a)	Intensity	Type	Epicentre	Remark
576	02	30	33				—	I	D		1030
577	03	01	20				0.1	〃	〃		1031
578	04	17	35		0.2		0.2	〃	〃		1035
579		39	10				0.1	〃	C		1036
580	11	10	26		0.5	2.0	0.1	〃	B		1049
581		13	54		0.3		0.1	〃	〃		1050

	h	m	s	s	m	m	mm				
582	12	52	09				0.1	I	B		1051
583	14	06	31				0.1	〃	D		1052
584		10	32	9.0	0.8	3.0	0.2	〃	A	Off Huttu	1053
585		12	27		0.1		0.1	〃	〃		1054
586	15	21	05	7.3	0.7	1.5	0.3	〃	B	N. Kadusa	1059
587		22	46	7.3	1.0	5.0	1.7	II	〃		1060
588	18	46	12	9.8	0.5	5.0	0.3	I	〃	Central Kadusa	1067
589	22	03	57	6.0	0.3	3.0	0.2	〃	〃		1068
590	23	08	00	9.5	0.5	3.0	0.2	〃	A	Central Sagami	1069
591		30	50				0.1	〃	D		1070
592		57	14		0.2		0.1	〃	〃		1072

September 12

593	02	22	38		0.2		0.1	I	D		1075
594	04	40	28				0.1	〃	〃		1076
595	06	07	51				—	〃	〃		1077
596	10	59	45	7.0	0.5	5.0	0.2	〃	A		1087
597	11	27	59					〃	D		1088
598	17	50	47	9.7	1.5	10	0.7	〃	A	S. Sagami	1094
599	19	17	05				0.1	〃	D		1095
600	23	28	13				0.1	〃	〃		1096
601		25	47	9.3	1.5	6.0	0.8	〃	A	Miura Pen.	1097

September 13

602	00	45	56				0.1	I	A		1098
603	04	54	47	7.1	0.4	2.0	0.5	〃	B	N. Kadusa	1100
604	05	01	51				0.1	〃	D		1101
605		31	48				0.1	〃	〃		1102
606	08	41	13		0.3		0.1	〃	B		1104
607	13	53	29				—	〃	D		1116
608	17	09	08					〃	A		1119
609	18	33	47				0.1	〃	D		1120
610	21	58	04	10.3	0.5	2.0	0.1	〃	B	N. Awa	1121

September 14

611	00	05	02		0.5		0.1	I	B		
612	01	15	11	9.6	0.3		0.3	〃	〃	S. Kadusa	1124
613		54	38				0.1	〃	A		1125

No.	Time of occurrence			Duration			Max. range (2a)	Intensity	Type	Epicentre	Remark
				Prel. trem.	Princ. port.	Total					
	h	m	s	s	m	m	mm				
614	02	33	51	6.7	0.2		0.1	I	B	Near Inbanuma	1126
615		35	16		0.1		0.1	〃	D		1127
616		51	34	7.0	0.3	2.0	0.1	〃	B	Near Yatimata	1128
617	03	10	37		0.2		0.2	〃	D		1129
618		43	53				—	〃	〃		1131
619	08	13	03				—	〃	〃		1134
620	10	26	43				—	〃	〃		1136
621	15	33	33	7.7	1.0	10	2.6	II	C	Near Usikunuma	1141
622	21	17	18				0.1	I	A		1144

September 15

623	00	46	22				—	I	D		1147
624	02	17	50	8.1	0.7	4.0	0.1	〃	〃		1148
625		41	55	8.7	1.0	9.0	1.3	II	A	W. Musasi	1150
626	07	36	04				0.1	I	D		
627	11	31	14	9.0	0.5	3.0	1.2	II	C	W. Simôsa	1153
628	13	09	41				—	I	D		1156
629	14	13	36				0.1	〃	A		1157
630	15	18	57	7.7	1.0	2.0	0.4	〃	B	Near Tiba	1158
631	16	34	55	7.0	1.5	3.0	0.4	〃	C	Near Noda	1159
632	17	35	46				—	〃	D		1160
633	18	38	00				0.1	〃	〃		1161
634	22	51	50		0.2		0.1	〃	B		1163

September 16

635	00	25	46	12.5	0.5	5.0	0.2	I	B	Off Kuzyu-kurihama	1165
636	08	12	42				0.1	〃	D		1170
637	17	19	13	7.3	0.8	6.0	0.2	〃	B	Near Sakura	1171
638	18	04	22	5.5		1.0	—	〃	D		1173
639	20	41	35			1.0	—	〃	〃		1175

September 17

640	03	21	42	10.2	0.4	2.0	0.2	I	B	Off Kuzyu-kurihama	1177
641	04	59	36				—	〃	D		

	h	m	s	s	m	m	mm				
642	05	55	13	13.6	0.3	2.0	0.1	I	A		1178
643	07	14	10				—	〃	D		1180
644	09	09	06	8.2	1.0	7.0	0.2	〃	A	E. Sagami	1181
645		49	42			0.7	—	〃	D		1182
646	10	02	34				0.1	〃	A	Off Manaduru	
647	12	40	44	61.4	2.0		2.1 (T=12.2)	II	〃	Near Hatidyo Is.	1183
648	19	02	45				—	I	D		1185
649	19	04	34				0.1	〃	〃		1186
650	21	18	14		0.2	3.0	0.1	〃	B		1188

September 18

651	02	28	28	5.2		2.0	0.1	I	D		1192
652	07	05	28	5.2	0.3	3.0	0.1	〃	B		1193
653	09	27	45	9.8	0.7	5.0	0.4	〃	C	Kasumigaura	1194
654	10	36	51				—	〃	D		
655	19	10	54			3.0	0.1	〃	A		1197
656	20	11	57			1.0	0.1	〃	D		1198

September 19

657	01	18	24	5.0		2.0	0.1	I	D		1199
658	02	06	58	6.5		3.0	—	〃	A		1200
659	03	11	40	6.3		2.5	—	〃	D		1202
660	04	28	40			2.5	0.1	〃	A		1203
661		43	41	6.0	0.3	2.0	0.3	〃	D	Central Musasi	1204
662	07	08	14	8.9	0.8	5.0	0.2	〃	A	N. Musasi	1206
663	09	19	50	9.3	0.2	2.5	0.1	〃	D		1208
664	16	20	50	7.8		3.0	0.1	〃	A		1213
665		42	26				—	〃	D		
666	18	08	43				—	〃	B		1214
667	20	23	24				0.1	〃	D		1216

September 20

668	00	04	57	8.3	0.8	5.0	0.1	I	B	Central Kadusa	1217
669	01	25	36	11.2	0.7	5.0	0.3	〃	〃	S. Kadusa	1219
670		32	29				—	〃	D		
671	05	09	53	8.8	0.3	5.0	0.1	〃	A	Off Yokosuka	1220 Vol. type
672	12	47	57	10.4	0.6	9.0	0.1	〃	〃		1223
673	18	30	04	8.8	1.0	4.0	0.2	〃	〃		1227

No.	Time of occurrence	Duration			Max. range (2a)	Intensity	Type	Epicentre	Remark
		Prel. trem.	Princ. port.	Total					
September 21									
	h m s	s	m	m	mm				
674	05 43 40	7.3	1.3	10	0.3	I	B	N. Kadusa	1234
675	08 20 22	7.5	0.4	2.0	0.1	〃	〃		1235
676	22 10	8.9	2.3	10	0.9	〃	〃	N.W. Simôsa	1236
677	12 37 32				—	〃	D		1239
678	14 06 02				0.1	〃	〃		1242
679	17 05 31	6.7	0.4	3.0	0.2	〃	B	N. Kadusa	1244
680	23 40 04	9.1	0.8	7.0	0.2	〃	〃	〃	1248
September 22									
681	06 07 41				0.1	I	D		1249
682	07 43 46		0.2		0.1	〃	〃		1250
683	13 36 41				0.1	〃	A		
684	15 52 26				0.1	〃	D		1255
685	17 12 38	10.4	0.6	3.0	0.1	〃	B	E. Kadusa	1256
686	23 42 17	6.6	0.8	5.0	0.4	〃	〃	Near Tiba	1259
September 23									
687	00 42 26	6.3	0.3	4.0	0.1	I	B		1260
688	23 35 49	5.3		1.0	0.1	〃	D		1262
September 24									
689	12 16 27				0.1	I	B		
September 25									
690	00 17 17				0.1	I	A	Hakone	1266
691	14 21 36				—	〃	D		1267
692	23 04 38	7.9		1.6	0.1	〃	A		1268
September 26									
693	00 57 15	5.3		1.0	0.1	I	D		1269
694	04 49 45				—	〃	〃		1270
695	06 23 06	8.9	1.2	5.0	0.2	〃	B	N.E. Awa	1271
696	07 27 37				0.1	〃	〃		

	h	m	s	s	m	m	mm				
697	13	03	51	9.2	0.8	5.0	1.1	II	C	Near Koga	1272
698	14	01	56				—	I	D		
699	17	20	30		0.2	1.0	0.1	〃	A		1273
700		24	03	16.0	3.0	80	26.0 (T=2.3)	III	〃	$\lambda=139^\circ\ 28'.3$ $\varphi=\ 34^\circ\ 40'.7$	1274
701		27	21				0.1	I	〃		
702	18	39	45	7.3	1.0	10	1.4	II	C	Near Usiku-numa	1277
703	22	55	52	14.4	3.0	10	0.5	I	A	Off E. Awa	1280

September 27

704	01	07	36	13.3	2.0	6.0	0.4	I	A	Uraga Channel	1281
705		54	07				0.1	〃	D		1283
706	04	26	58				0.1	〃	〃		1284
707	05	07	54	7.3	1.3	10	0.8	〃	A	E. Tokyo Bay	1285
708	10	34	36	9.4	0.4	4.0	0.1	〃	B	Central Kadusa	1286
709	12	14	57					〃	D		1287
710	20	06	35	6.5	0.2	2.0	0.1	〃	〃		1289

September 28

711	06	11	22	9.0	0.8	2.0	0.1	I	B	W. Kadusa	1292
712		14	20	14.7	0.4	15	0.2 (T=0.7)	〃	A		1293 Vol. type
713	07	20	29					〃	〃		1294
714	19	14	23	4.6	0.5	3.0	0.4	〃	C		1295

September 29

715	06	27	49	11.0	0.8	7.0	0.2	I	B		1296
716	09	52	03	9.0	0.8	3.0	0.1	〃	A	E. Sagami	1299
717	10	33	26	6.0			0.1	〃	〃		1300
718	12	00	53	9.5	2.0	10	0.4	〃	〃	Sagami Bay	1301

September 30

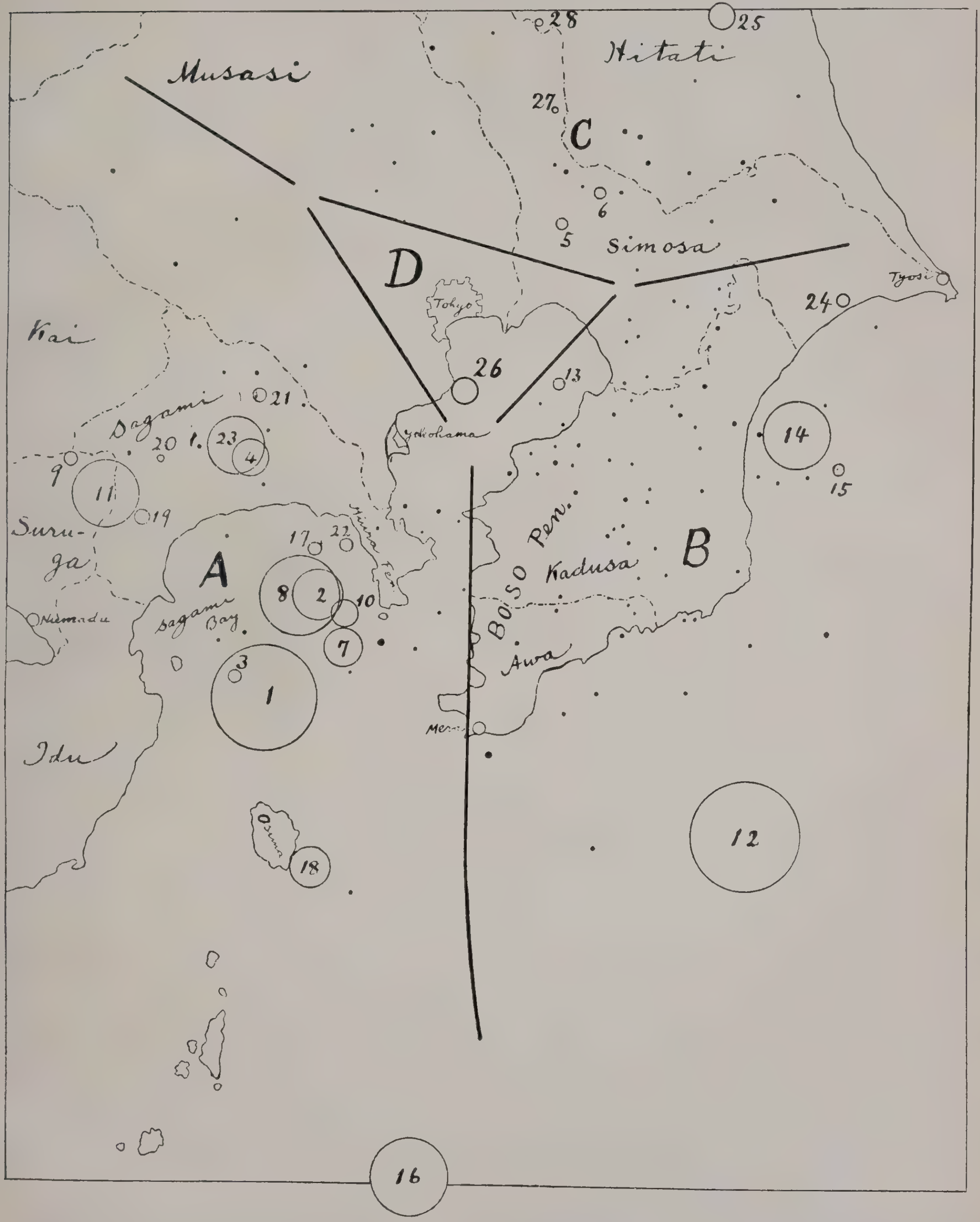
719	10	17	00				—	I	D		
720	15	26	10	11.2	2.0	10	0.5	〃	B	S. of Miura Pen.	1303

October 1

721	02	43	18	11.9	0.4	6.0	0.1	I	B	N.W. Kadusa	1
722	04	51	38	13.6	0.7	5.0	—	〃	A		2 Vol. type
723	05	43	39	13.0	0.3	4.0	0.1	〃	B		3
724		51	36	11.3	0.8	5.0	0.1	〃	〃		4

PL. I.

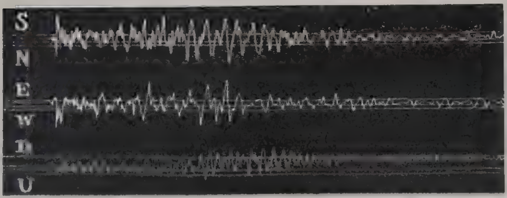
Map showing the distribution of the origins of the earthquakes registered at Tokyo in Sept., 1923, and of the principal aftershocks of later occurrence.



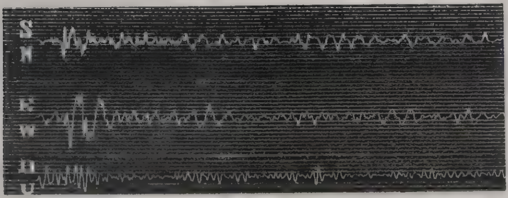
Each circle with numerical suffix indicates the earthquake in Table I.

Each dot without suffix indicates the earthquake with its intensity as follows:—
·......slight, •......moderate, ●......strong.

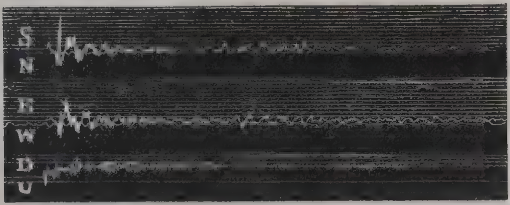
A-type. Earthquake of Nov. 23, 1923.
(No. 22, Tab. I.)



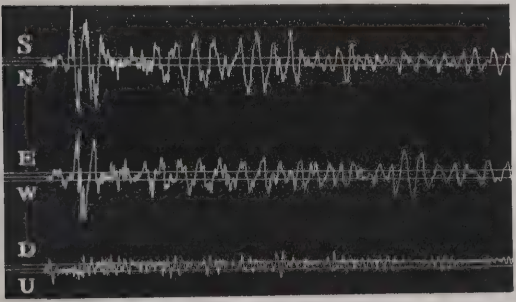
:B-type. Earthquake of Aug. 6, 1924.
(No. 24, Tab. I.)



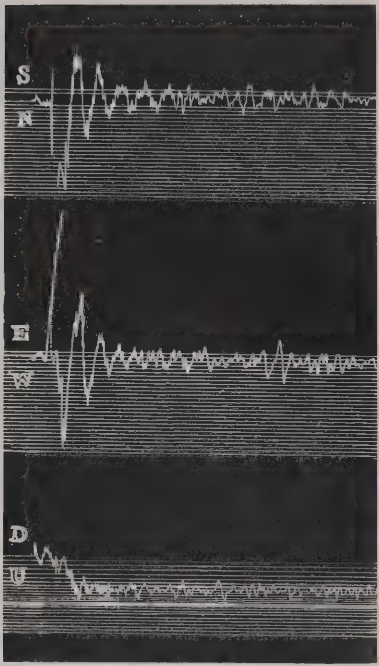
B-type. Earthquake of Sept. 2, 1923.
(No. 13. Tab. I.)



C-type. Earthquake of Sept. 18, 1924.
(No. 25, Tab. I.)

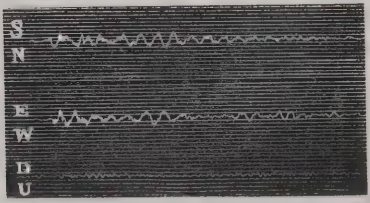


Earthquake of Aug. 3, 1926.
(No. 26, Tab. I.)

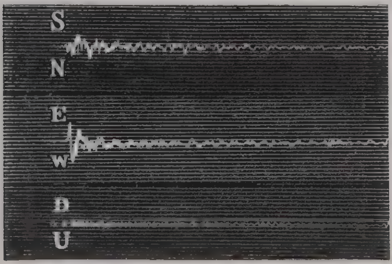


(Rather D-type.)

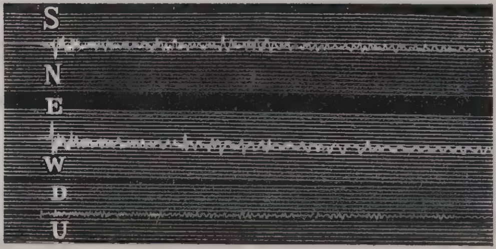
B-type. Earthquake of Oct. 5, 1924.



C-type. Earthquake of Jan. 1, 1928.
(No. 27, Tab. I.)

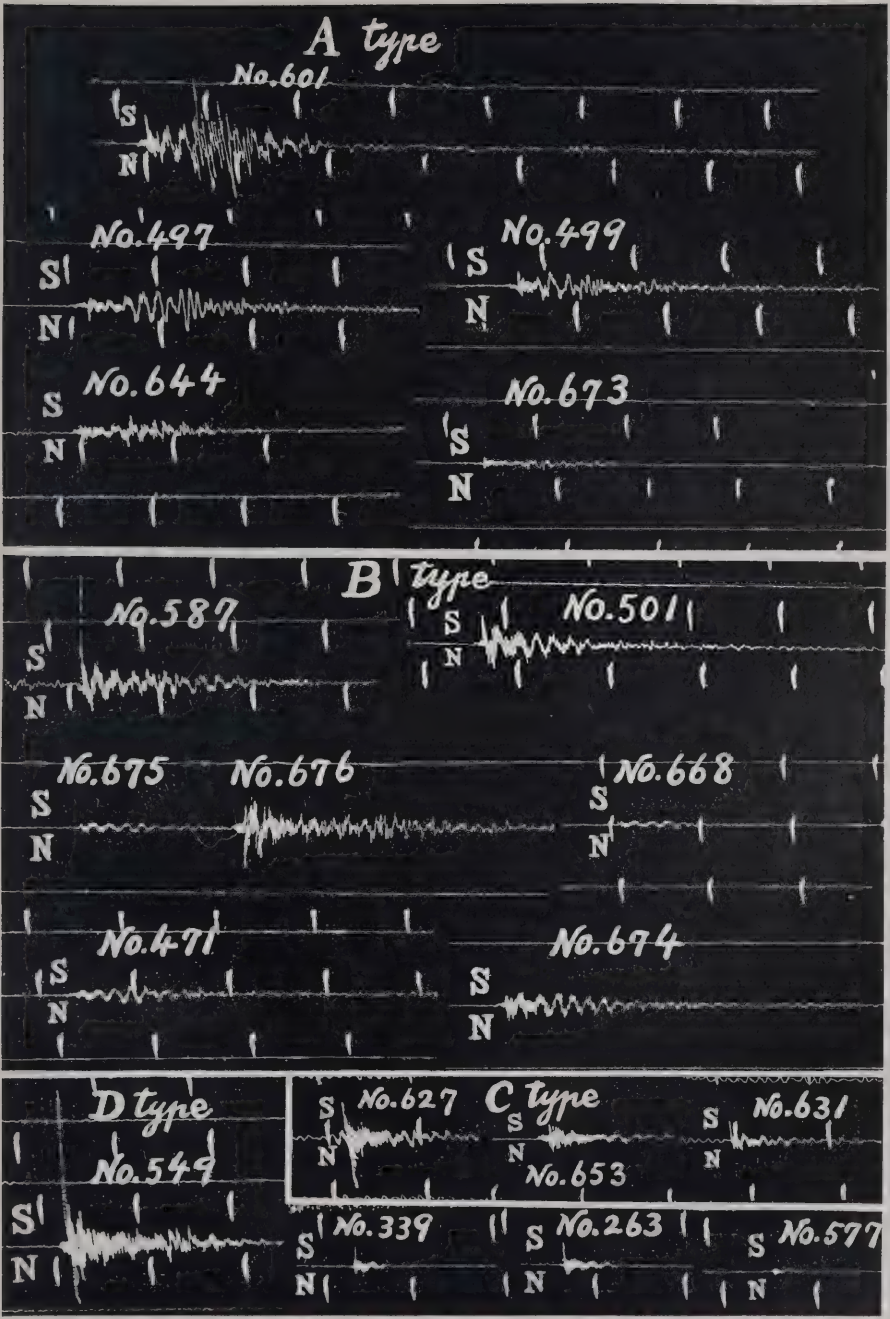


C-type. Earthquake of Feb. 12, 1928.
(No. 28, Tab. I.)



Earth's movements in natural size.

PL. III.



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Page

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Torahiko Terada and **Seiti Yamaguti**: On the Fluctuation of Sea Level before and after the Great Kwantô Earthquake, 1923—Effect of Cyclones. 113–123

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September, 1928

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TOKYO

September, 1928

On the Change in Water Level of Rivers Observed on the Occasion of Great Earthquake, 1923.

By

Seiti Yamaguti, *Rigakusi.*

The results of some investigations on the propagation of sea-waves caused by the Great Earthquake of 1923, along the Pacific coast of Japan was already reported by T. Terada and S. Yamaguti in the Report of the Earthquake Investigation Commitee No. 100 B (in Japanese). The present report may be regarded as a continuation of the above, dealing mainly with the sea-waves recorded at different river stations in the Kwantô District.

Immediately after the earthquake the tide-gauge records of the different river stations were kindly placed at the disposal of the committee by the courtesy of the Department of Home Affair and also of the City of Tokyo. On examining these records, it was found that the sea-waves caused by the earthquake have imprinted their traces upon the fluviograms at different stations situated along the Rivers Arakawa and Nakagawa of which the mouths open to the head of the Bay of Tokyo. As to the River Edogawa, only one station, Horie, showed some traces of waves while at the other two, Gyôtoku and Matudo, no conspicuous trace could be found so that we were obliged to put this river out of account in the later discussion on the mode of propagation of waves along the river course.

Besides the trace of the sea-waves, the most remarkable feature of the fluviograms is that they reveal mostly some decided abrupt change in the mean water level before and after the earthquake, as will be seen from many of the records reproduced in Fig. 1.[1]

The contents of the present report may therefore be conveniently divided into the three parts, i. e. (1) the abrupt change in water level recorded by fluviograph is compared with the change in the height of land above sea level derived from the results of the precise levelling surveys carried out by the Land Survey Department of the Imperial Army before and after the earthquake, and thence the absolute vertical change in height of the datum line used for reference in the levelling work, is estimated; (2) and (3) the rate of damping and the velocity of waves along the river course were determined for the three rivers Arakawa, Nakagawa and Tonegawa. The investigation thus far made is of a provisory character, but may be of some interest for seismologists as well as those concerned with geodetic works.

---

[1] The records which are already reproduced in the R. E. I. C. 100 B, are here omitted: Sirahige, Huruisiba etc.

Most of fluviographic records here examined are those obtained by the Department of Home Affair and some by the Authorities of the City of Tokyo as already mentioned. The data for the levelling survey are those obtained by the Land Survey Department. These materials were placed at my disposal by the kind intervention of Prof. T. Terada.

I. Comparison of the Vertical Displacement obtained by the Levelling Survey with That derived from the Fluviograph Record.

For the determination of the amount of difference between the mean water levels before and after the earthquake, we took the means of only one, or two days, preceding and succeeding the event respectively, as the effect of rain or other meteorological factors may enter into consideration if we take a longer interval of time. The method of calculation adopted is as follows.

The mean value of the heights of the level at the four tidal maxima and four minima preceding the noon of Sept. 1 was calculated which will be denoted by M_b. Similarly, the corresponding mean value after the same epoch was obtained which we denote by M_a. Then, the difference $x=M_b-M_a$ was calculated for each station and plotted on the $x-y$ diagram against the corresponding value of the vertical displacement y obtained by the levelling survey as ordinate, as shown in Fig. 3. The value of y is the amount of the vertical displacement of the station interpolated from the result of the survey and referred to the datum line at Tokyo which is assumed fixed. The change was obtained from the difference between the results of the surveys carried out in the two epoch 1918 and 1926 and may therefore be partly due to a slow chronic crustal movement, or, in some cases, due to a very local disturbance of the station, though we have many reasons to believe that a greater part of this change was completed at the time of the earthquake.

On the other hand, it will be noted that the value of x is the sudden change in the relative water level just at the time of the event. We cannot therefore expect *a priori* that x and y will show a perfect correlation. In the annexed Table[1] the values of x and y are given in which the positive values signify upheavel of the earth crust and the negative depressions.

TABLE I.

Change of level, before and after the great earthquake on sept. 1, 1923.

Stations	y	x_1	x_2
Kanaedu	mm. 80	mm. 21	mm. −136
Kawaziri	84	6	−61
Itinobume	84	−9	−45
Ôtasinden	91	−45	−64
Tyôsi	97	−50	−20
Usibori	88	−39	−24
Ga	84	−45	−9
Matudo	38	3	(−336)
Horie	−43	−182	−176
Todabasi	−123	−340	−270
Iwabuti	−110	−260	−200
Senzyu	−68	20	10
Kosuge	−119	−170	−150
Sinyado	−57	−272	−236
Kamihirai	−140	−210	−180
Komatukawa	−179	−180	−170
Tomabasi	−240	−82	
Sibaura	+3	−227	−275
Sirahigebasi	−61	−206	−242
Huruisiba	−156	−197	

Though the points plotted in Fig. 3 show a considerable dispersion, it will be seen that they form apparently two groups, one including the stations in the vicinity of Tokyo and the other containing the stations along Tonegawa. The latter group shows a large positive value of y with a small negative value of x. This will suggest that the datum line assumed fixed has actually undergone a decided depression amounting to about 100 mm.

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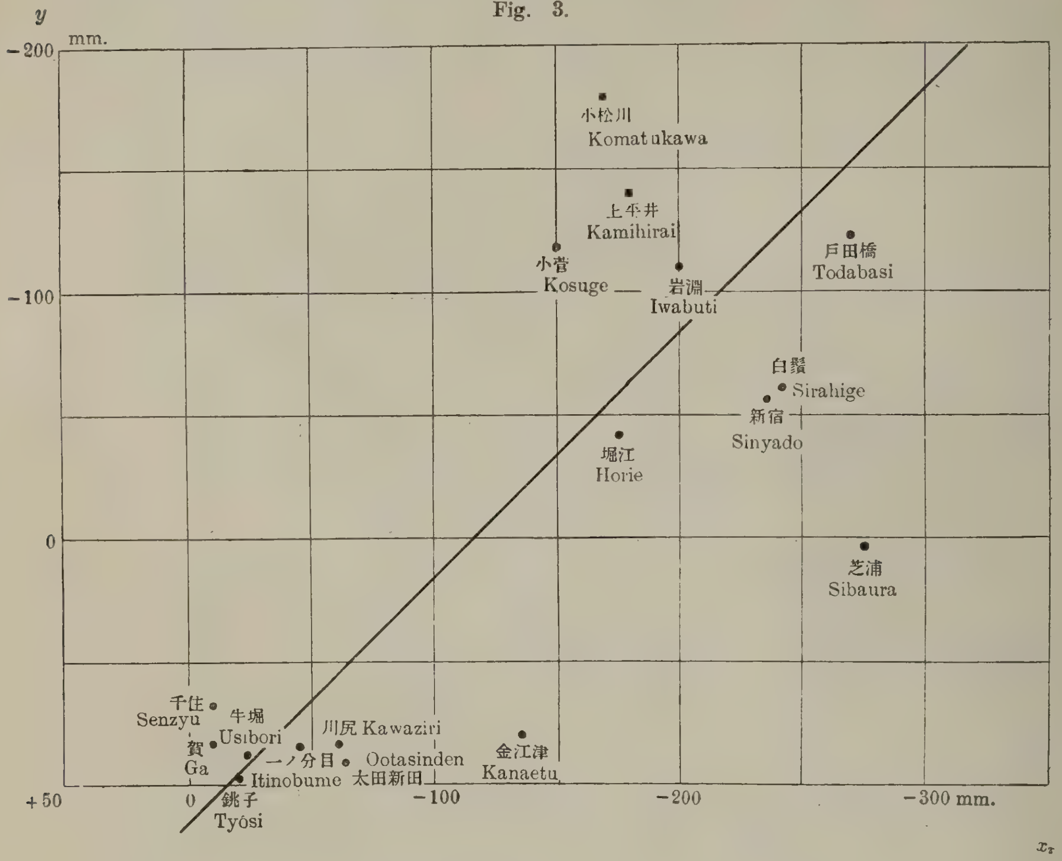
[1] In this table the values of x obtained by the above method are under the column x_2.

Fig. 3.



For a trial, the linear relation

$$y = a + x$$

was assumed and the constant a was determined by the method of least square. The result is

$$a = 115 \pm 14 \text{ mm.}$$

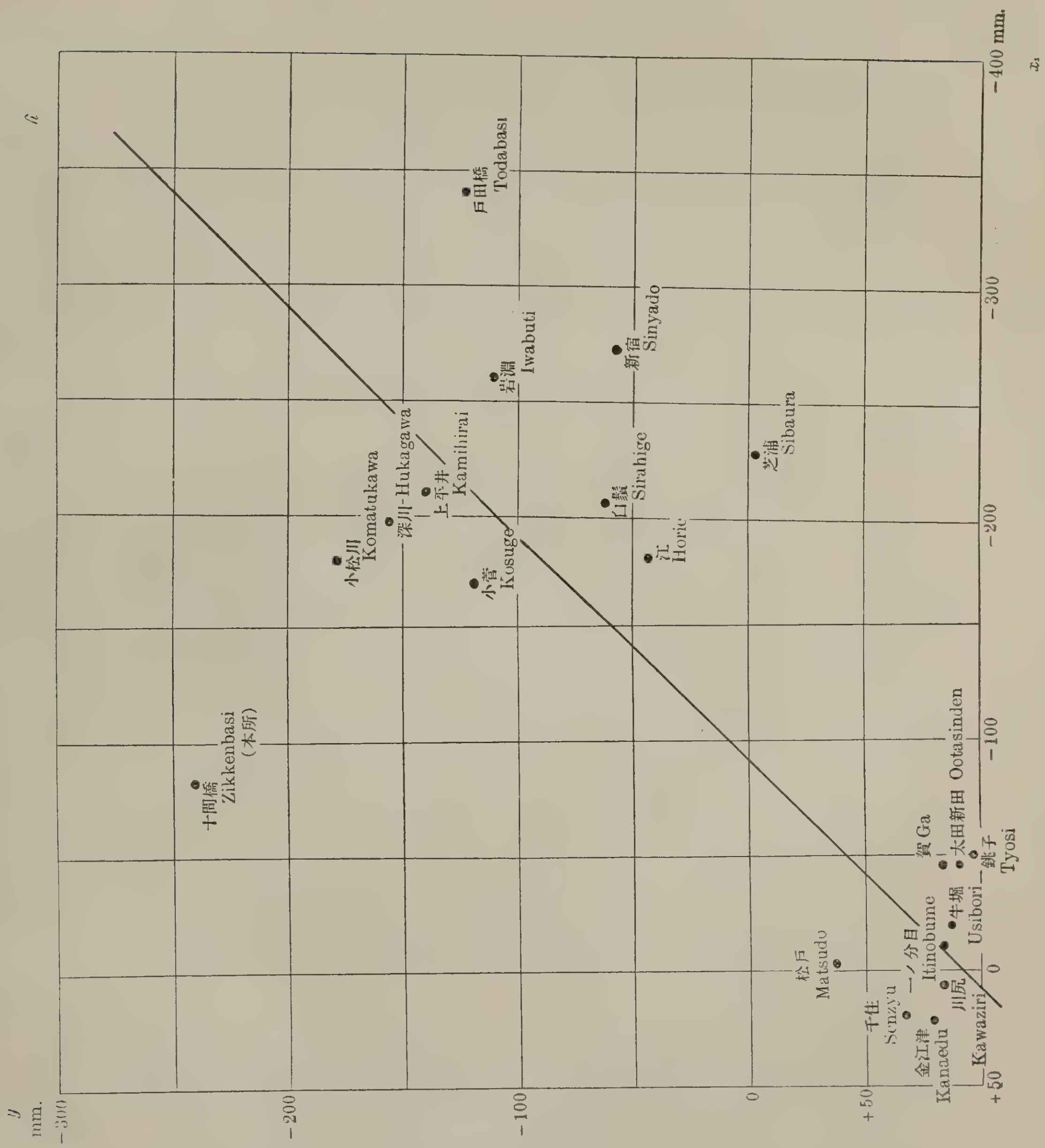
where the number of points used is 17.

Next, we took two maxima and minima, instead of four, of the water level before and after the earthquake for evaluating M_b and M_a, and thence x.[1] Using this value of x, the $x-y$ diagram was plotted as

---

[1] This value of x is given in Table I as x_1.

Fig. 4.


y
mm.
−300
−200
−100
0
+50
x
−400 mm.
−300
−200
−100
0
+50
h
戸田橋
Todabasi
岩淵
Iwabuti
新宿
Sinyado
芝浦
Sibaura
白鬚
Sirahige
江
Horie
上平井
Kamihirai
深川-Hukagawa
小松川
Komatukawa
小菅
Kosuge
十間橋
Zikkenbasi
（本所）
松戸
Matsudo
千住
Senzyu
金江津
Kanaedu
一ノ分目
Itinobume
川尻
Kawaziri
牛堀
Usibori
賀 Ga
太田新田 Ootasinden
銚子
Tyosi

shown in Fig. 4. Calculating a by the similar method, we obtain

$$a = 92 \pm 15\,\text{mm}.$$

the number of points being 20. In this case the number of points is increased by 3, as the stations excluded in the former case on account of some defects of the records could now be utilized.[1]

According to the result of the latest find reductions both from the data of levelling survey and those of the mareograms, carried out by the Land Survey Department,[2] the datum line is shown to have been depressed by 86 mm., which agrees with our result at least in the order of magnitude. Thus, our present result, though of little value for determining the exact amount of depression of the datum line, will be of some interest at least in illustrating the possibility of utilizing fluviographic records for detecting the vertical displacement of land on the occasion of a great earthquake.

II. Relation between Amplitude of Waves and Distance from the Mouth of River.

Next, the relation was investigated which may hold between the distance of the station from the mouth of the river and the amplitudes of the sea-waves recorded at that station. For this purpose, the distance was approximately measured[3] from a suitable map and the amplitude was obtained by taking the mean value of the amplitudes of the first two conspicuous waves. The amplitude-distance diagram is shown in Fig. 5[4] in which the amplitude is given in mm. and the distance in km. The points for the three rivers Arakawa, Nakagawa and Tonegawa are respectively connected by curves. Referring to this Figure we may remark the following:

Comparing Arakawa with Nakagawa we may observe a striking difference in the rate of damping of waves. That Arakawa shows such a small rate of decay may probably be due to the fact that this river is of a considerable depth up to the distance here concerned and at

---

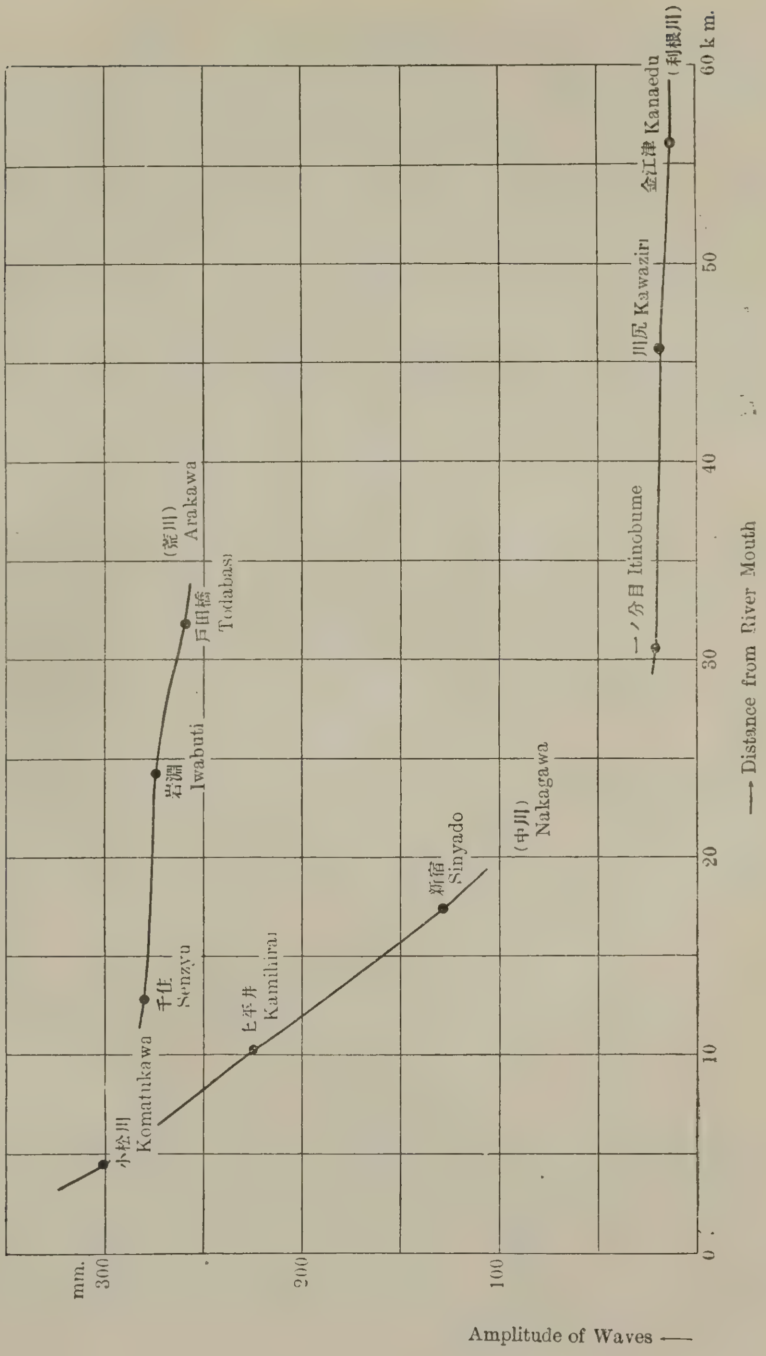
[1] The three stations are: (1) Matudo where the effect of rain appeared remarkably on the second day after the earthquake; (2) Zikkenbasi, Honzyô and (3) Huruisiba, Hukagawa where the records were defective. Referring to Fig. 4, Zikkenbasi shows an abnormal value of y which is probably due to a local disturbance of the benchmark.

[2] A diagram published by the department, May 1928.

[3] By means of a string applied along the river course depicted on the map.

[4] The two stations Zikkenbasi and Huruisi have been excluded in this case, as they are situated remote from the main river course, being in communication with it through system of narrow canals.

Fig. 5.


mm.
300
200
100
0
10
20
30
40
50
60 k m.
Amplitude of Waves ——
——→ Distance from River Mouth
小松川 Komatukawa
千住 Senzyu
岩淵 Iwabuti
戸田橋 Todabasi
(荒川) Arakawa
上平井 Kamihirai
新宿 Sinyado
(中川) Nakagawa
一ノ分目 Itinobume
川尻 Kawaziri
金江津 Kanaedu
(利根川)

the same time its breadth is markedly narrowed upstream.

On the other hand it is interesting to observe that the extrapolated amplitudes of waves for the mouth of Arakawa and Nakagawa respectively may give the same order of magnitude somewhat above 300 mm.

As for the river Tonegawa, we observe that the waves had been remarkably damped when they reached 30 km., while at Tyôsi, i. e. just outside the mouth of the river, the amplitudes are recorded as about 450 mm. This may, however, be easily understood if we consider that the mouth of this river is markedly contracted and the lower part of the stream traversed by the waves before reaching the station Itinobume is mostly shallow and wide, besides being in communication with the Lake Kasumigaura. It is rather interesting, therefore, to observe that the waves have affected the stations at such distances at all.

II. Velocity of Sea-waves in River.

To investigate the mode of propagation of sea-waves up the river course, the time of beginning of waves at each station was estimated from the mareogram as marked by a short vertical line in Fig. 2. The time of arrival thus obtained is plotted as the ordinate against the corresponding distance from the river mouth as the abscissa, as shown in Fig. 6.

Taking at first all the points for the three rivers indiscriminately, we may draw a straight line passing the origin of coordinate, i. e, $y=mx$, by inspection. From the estimated value of m we may obtain an averaged *gross* value for the velocity of propagation, v. Thus, we obtained

$$v=2.9\,\mathrm{m./s.}$$

Assuming, as is usual,

$$v=\sqrt{gh_m}$$

where h_m is the mean depth and g the accelration due to gravity, we obtain

$$h_m=0.86\ \mathrm{m.}$$

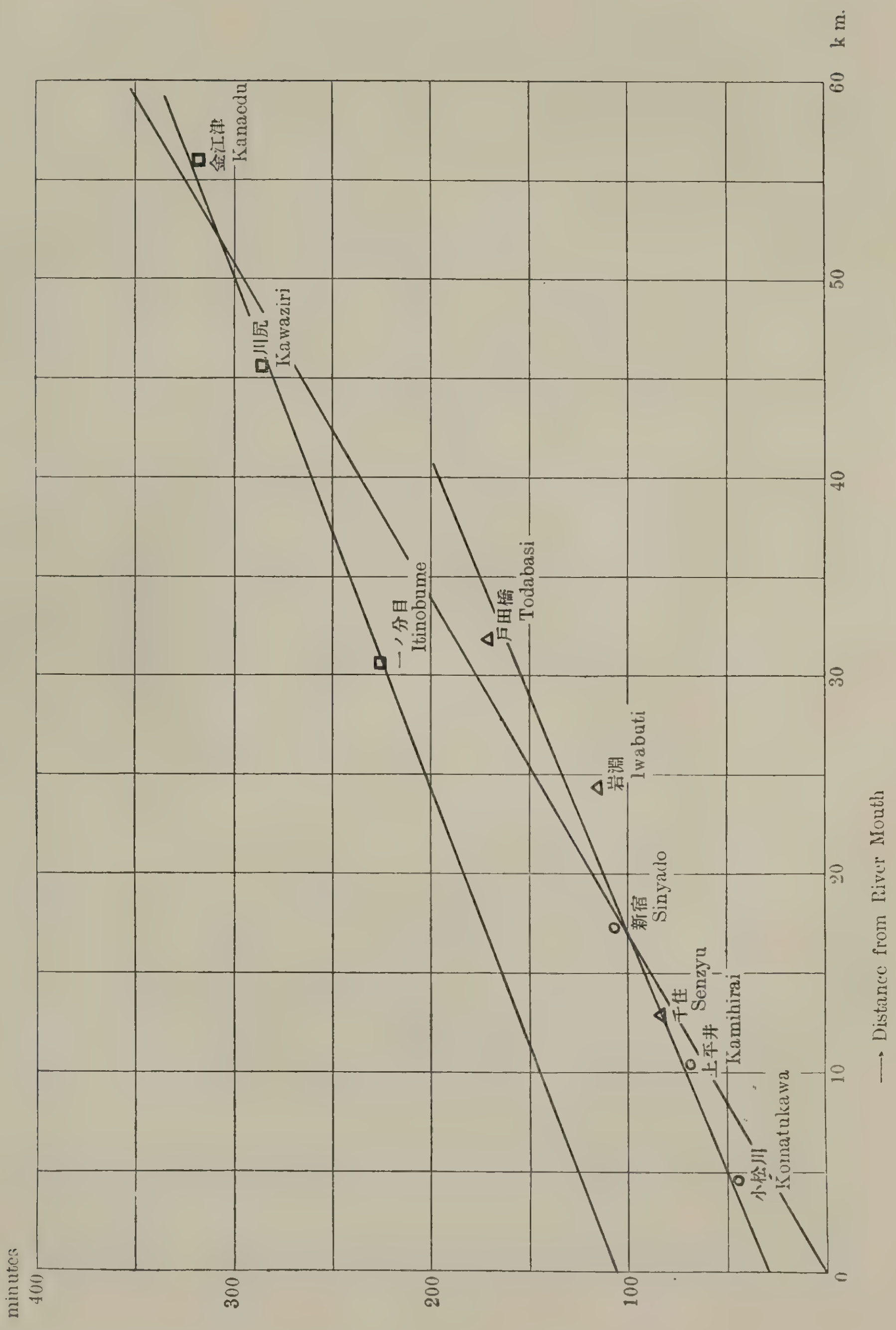
This value for the mean depth may appear too small considering that in the present case a maximum depth of 2 or 3 m. is allowable.

In the above diagram, we have taken as the origin of time for the time of propagation along Tonegawa, that time at which the waves arrived at the river mouth. The latter time may be determined from the mareogram obtained at Tyôsi[1] and agrees well with the result of

---

[1] The mareogram is given in the previons report, loc. cit.

Fig 6.


minutes
400
300
200
100
0
10
20
30
40
50
60
km.
→ Distance from River Mouth
金江津 Kanaedu
川尻 Kawaziri
一ノ分目 Itinobume
戸田橋 Todabasi
岩淵 Iwabuti
新宿 Sinyado
千住 Senzyu
上平井 Kamihirai
小松川 Komatukawa

calculation based on the assumption that the waves propagated from the epicentre in the Bay of Sagami. In the cases of Arakawa and Nakagawa the origin of time was taken at the time of the earthquake. Taking the latter two rivers together, excluding Tonegawa, we may observe that the points plotted (marked by ○ and △) may be connected by a straight line the point $x=0$ and $y=30$ mm., whence we may deduce that the waves occurred at the river mouth about 30 minutes after the earthquake. According to Honda, Terada and others[1] the calculated period of secondary undulations of the Bay of Tokyo is 222 minutes, whence the time required for the waves in traversing the length of the bay is to be estimated at the order of magnitude of 111 minute. Thus, it appears that the waves propagated into the rivers cannot have been originated in the centre of Sagami Bay. On the other hand, the mareogram at Yokosuka shows that the waves commenced at the mouth of the Bay of Tokyo just at noon. Moreover, some of the fluviograms here reproduced makes us suspect that the disturbances commenced earlier than are here assumed. Leaving the time of origin of the waves as an open question, however, we may estimate the velocity of propagation from the inclination of the straight line connecting the points for Arakawa and Nakagawa. Thus, we obtain

$$v=4.1 \text{ m/s.}$$

whence

$$h_m=1.7 \text{ m.}$$

which is plausible.

On the other hand, the straight line connecting the three points (marked by □) for Tonegawa shows an almost equal inclination to the coordinate axes as the line for the other two rivers above mentioned, but it cuts the time axis at about $y=100$ min. It appears, therefore, that either the waves have undergone a remarkable retardation in the lower stream or they were originated later than the main shock of the earthquake at 11 h 58 m, for example by one of the numerous aftershocks. The question may, however, be left for a future investigation.

In conclusion, I wish to express my best thanks to Prof. T. Terada for many useful suggestions given in the course of investigation.

---

[1] "Secondary Undulations of Oceanic Tides" Journ. Coll. Sci., Tokyo Imp. Univ., **24** (1906).

Fig 1. a

Stations in Arakawa

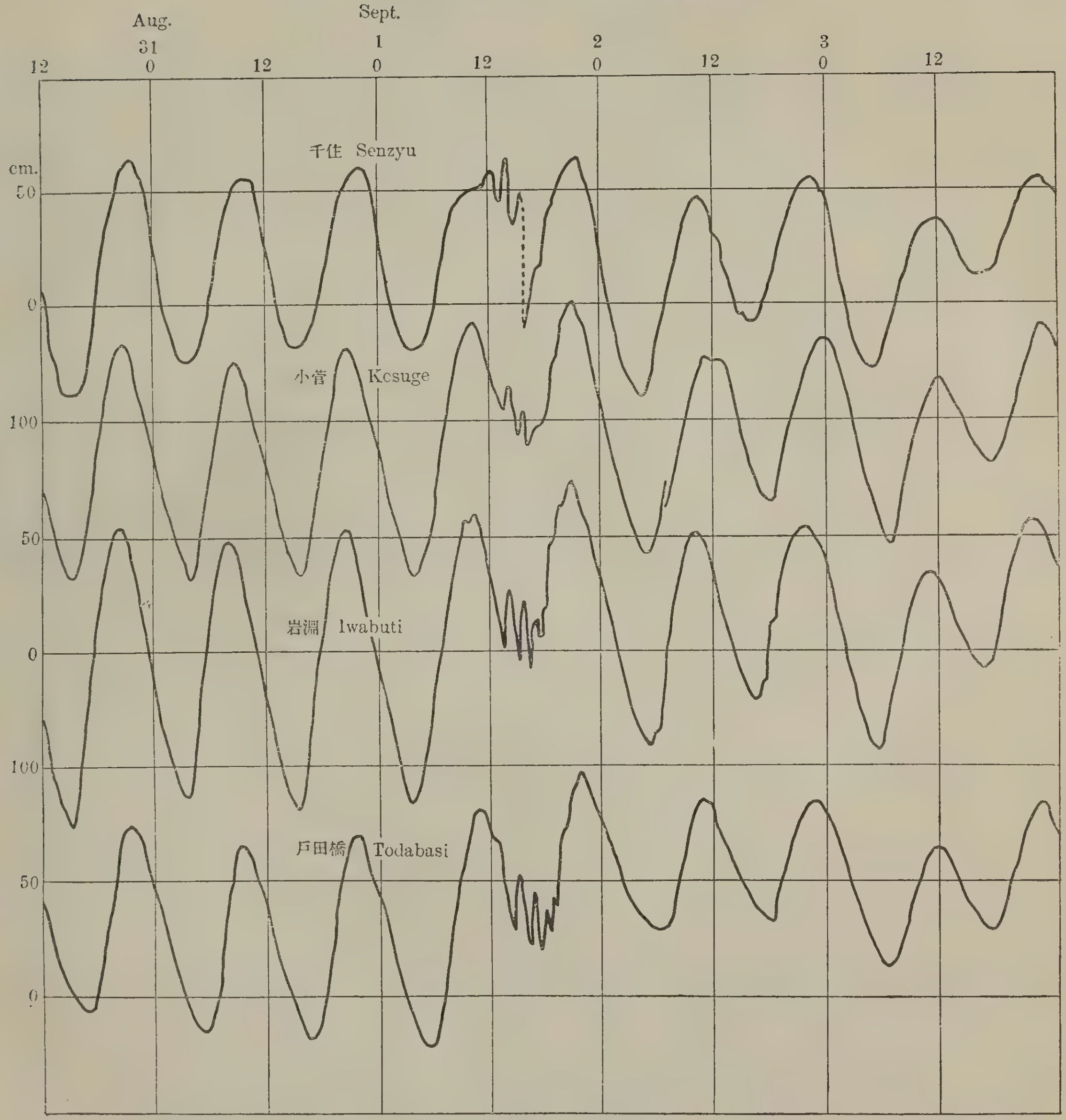


Fig 1. b
Stations in Edogawa

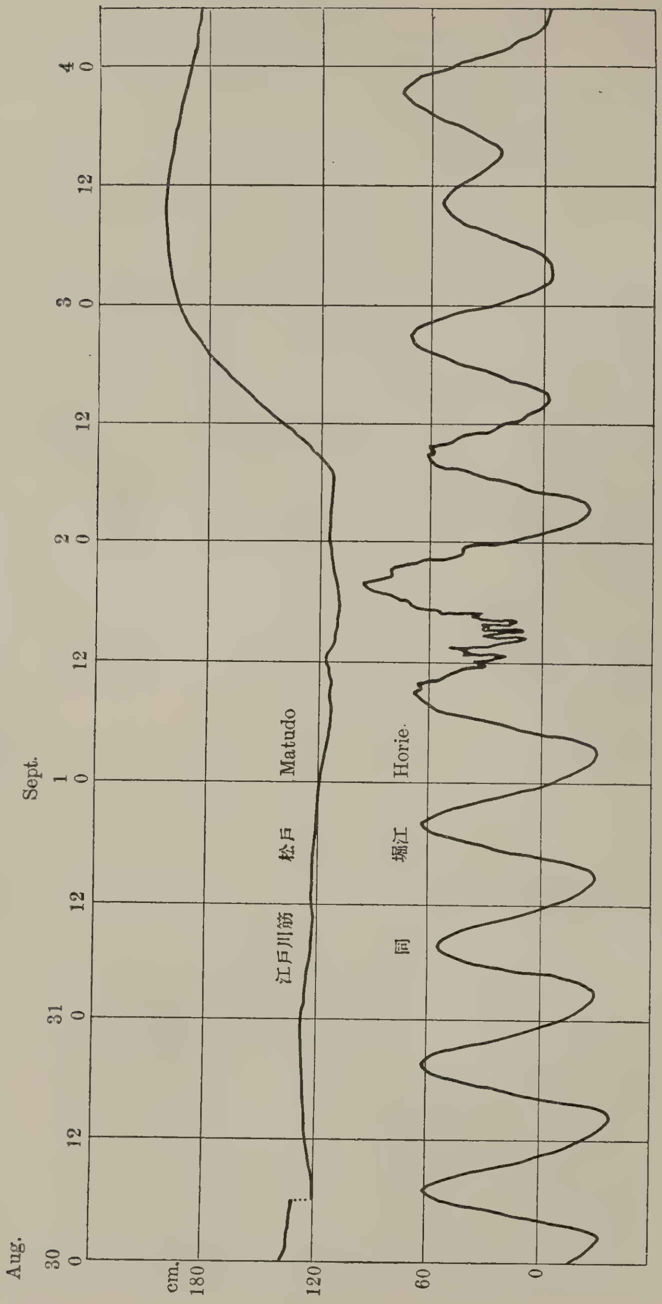


Fig 1. c

Stations in Nakagawa

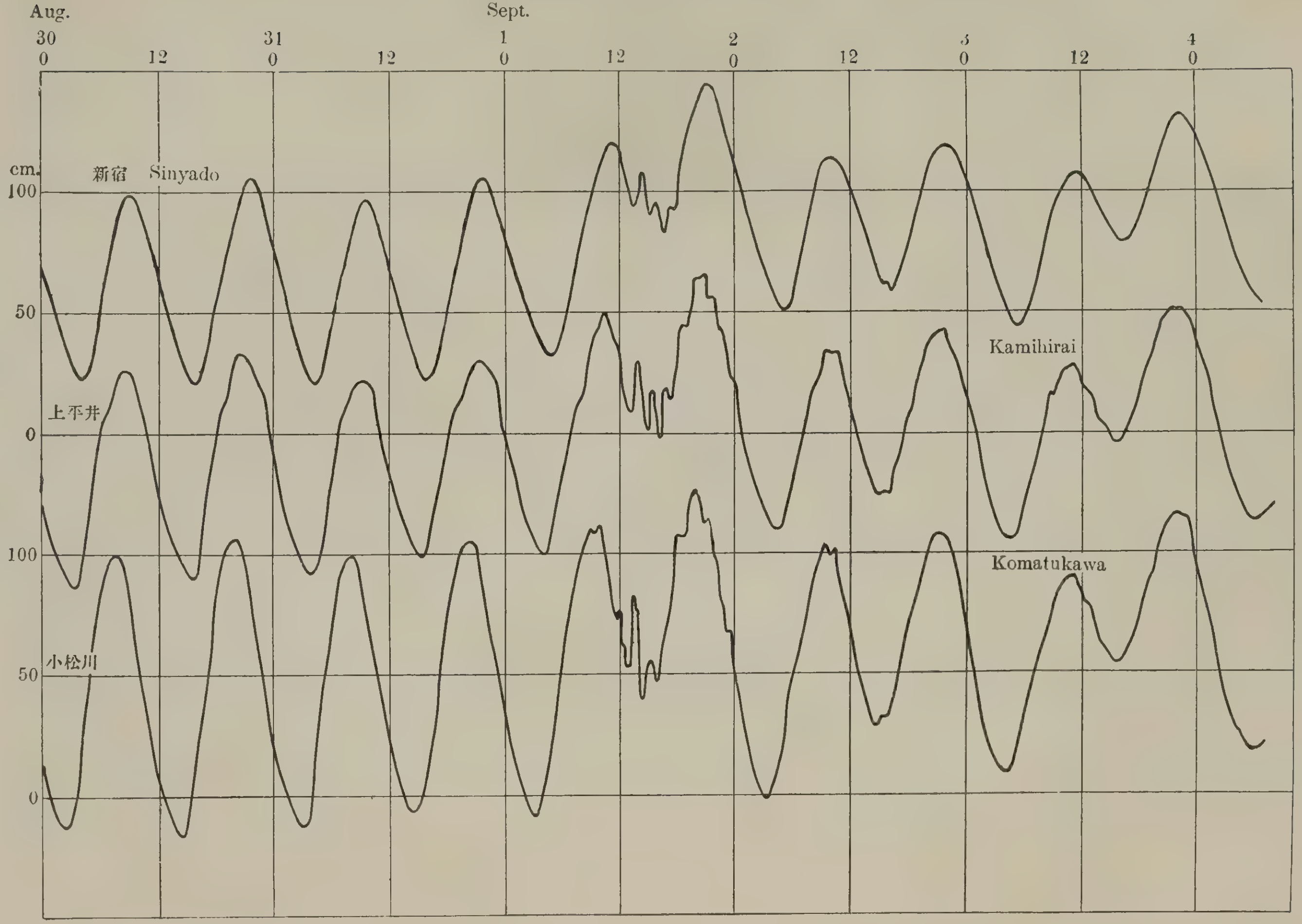
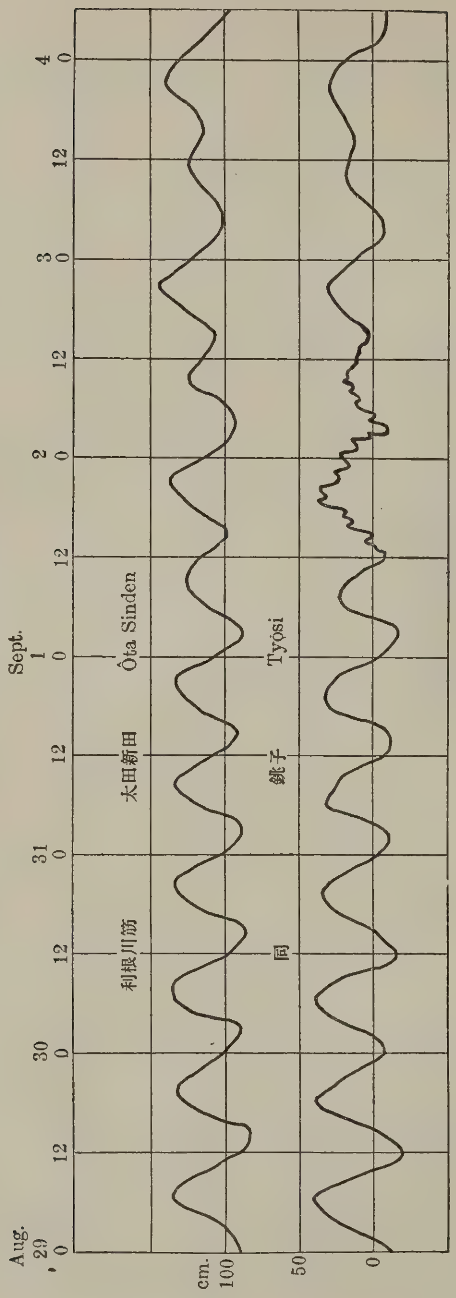


Fig 1. d

Stations in Tonegawa



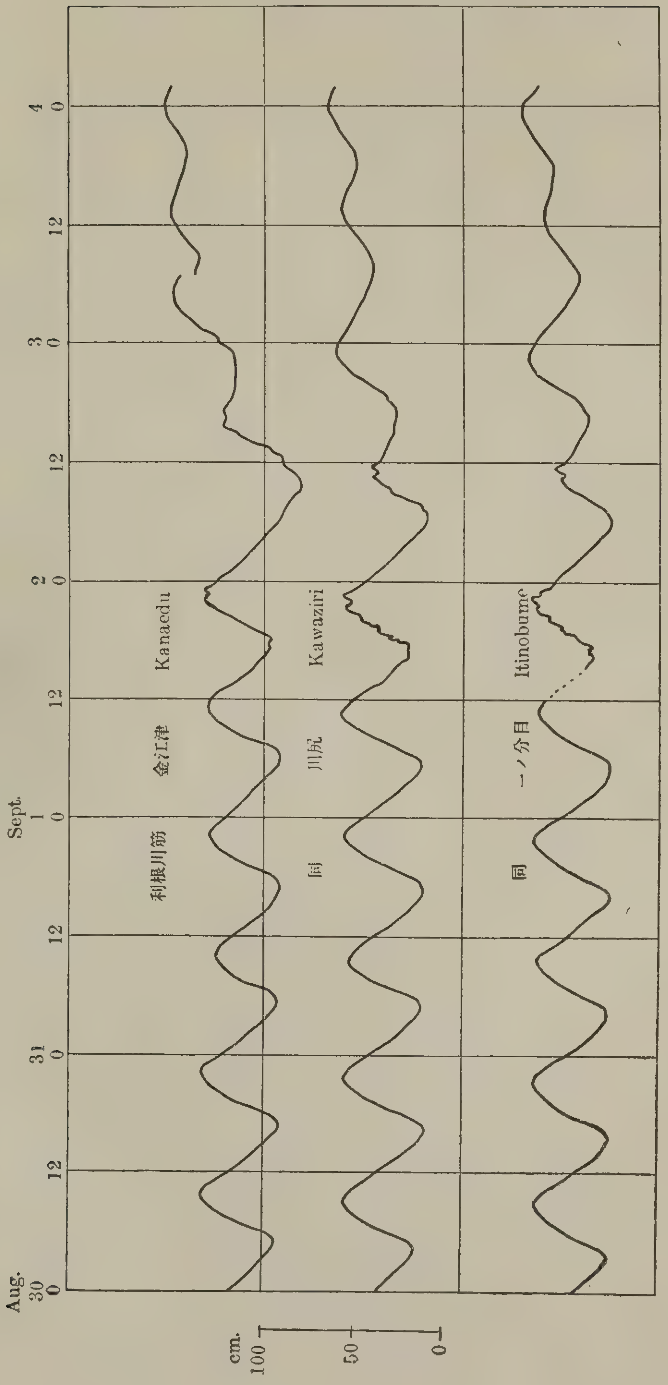


Fig 1. e

Stations in Tonegawa

Fig 1. f

Stations in Tonegawa

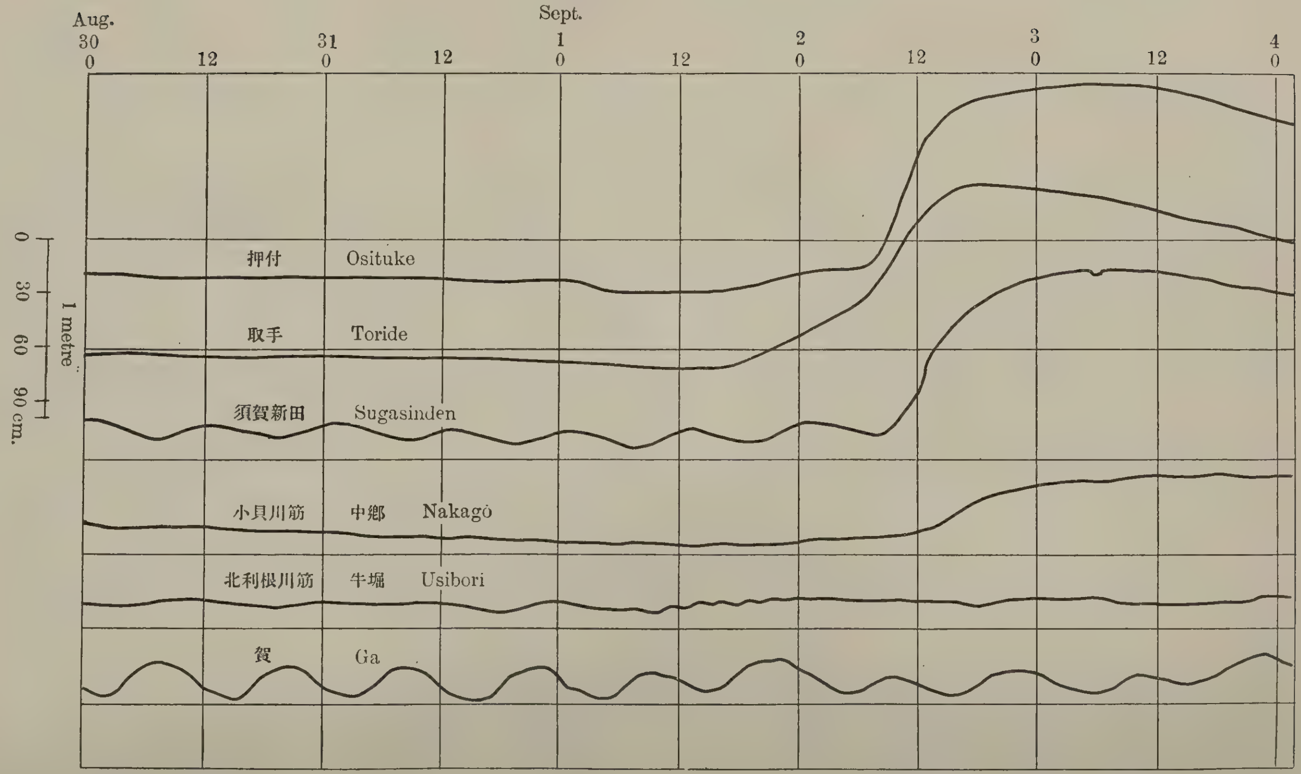
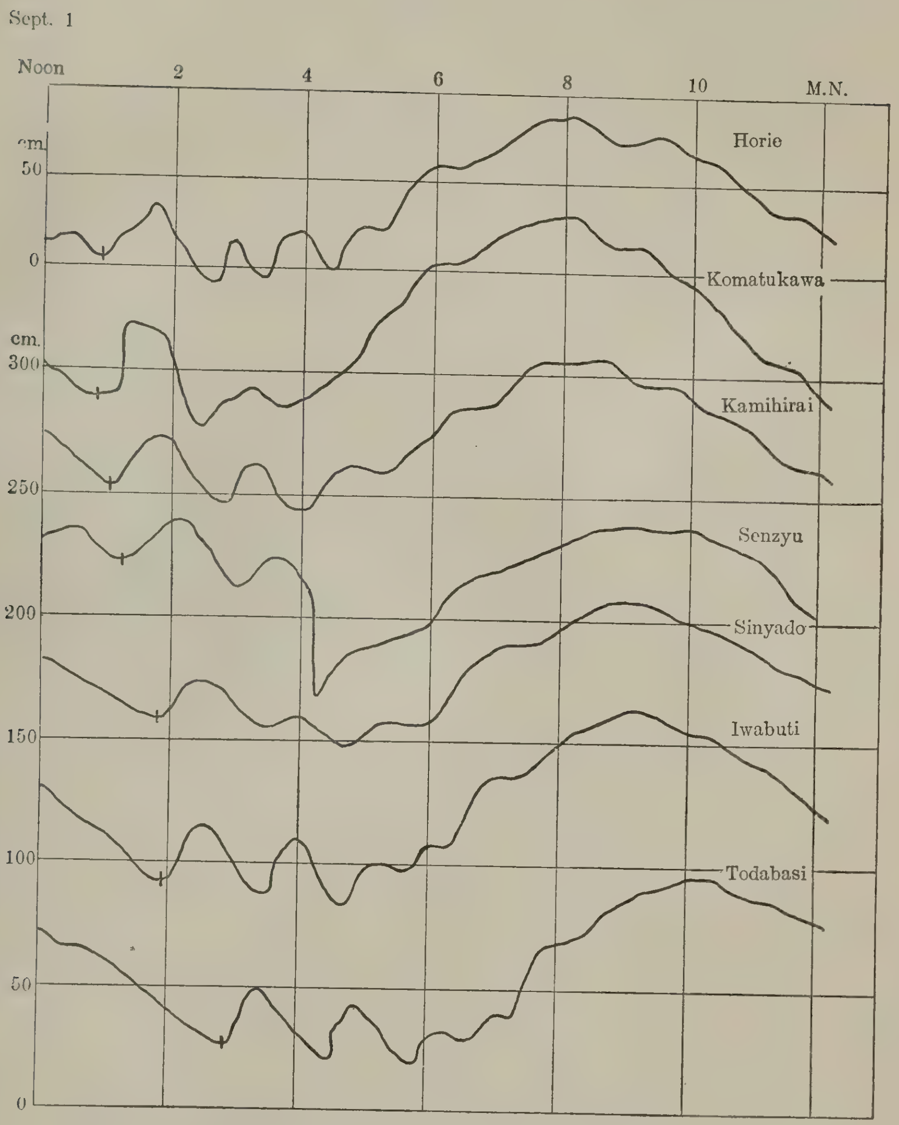


Fig 2. a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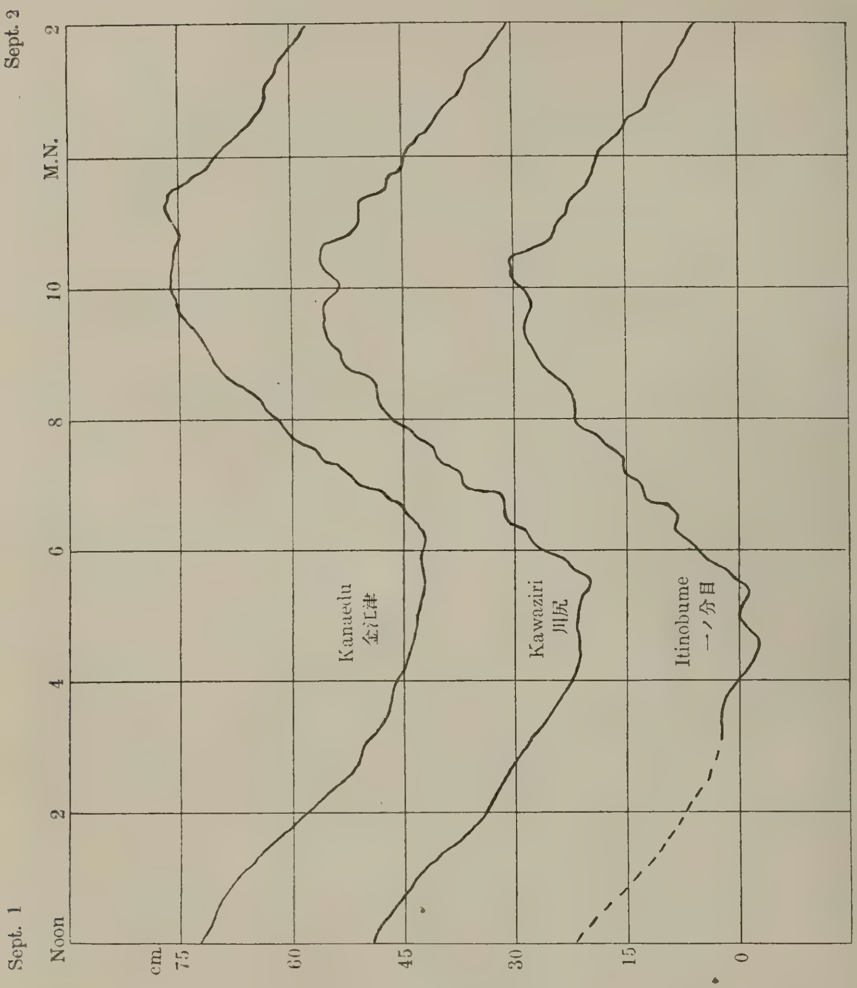
Todabasi

Fig 2. b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一ノ分目

On the Fluctuation of Sea Level before and after the Great Kwantô Earthquake, 1923—Effect of Cyclones.

By

Torahiko Terada and Seiti Yamaguti.

Immediately after the great earthquake of Sept. 1, 1923, the present authors undertook the investigation of the tide gauge records obtained at Aburatubo Mareographic Station with the purpose of detecting any possible slow fluctuation in the sea level which may have been caused by some vertical movement of the earth crust.[1] For this purpose, the daily values of the sea level of this station for 1923 and 1924, kindly placed at our disposal by the Land Survey Department, were subjected to examination. For the comparison, the data for Hososima, Hanasaki and Wazima were also consulted.

On plotting the daily values of the sea level as ordinates against the dates taken as abscissae, it appeared at first glance that the graph shows abnormally large fluctuation in two or three months following the earthquake.[2] We became, however, soon aware of the fact that the fluctuation of the daily mean barometric pressure in this region was also exceptionally large during the same epoch, so that no inference could be drawn as to the actual vertical movement of the earth crust, unless suitable corrections are applied to the observed values of the sea level, taking into account all the sensible meteorological effects.

Among the different meteorological factors affecting the sea level, the barometric pressure and its gradient may be considered most important, especially when we are concerned with the interdiurnal fluctuations within a short period such as a month or two. The variation of temperature of the sea water may also cause a sensible influence on the height of the sea level, as was recently shown by Prof. T. Nomitsu and

---

[1] At the time when the present investigation was begun, we were still unware of the real existence of such a remarkable slow vertical movement of the earth crust as recently revealed by the results of the repeated postseismic levelling survey carried out in the Tango earthquake district.

[2] Dr. T. Tokuda also noticed this fact and carried out some investigations.

Dr. M. Okamoto[1] with respect to the mean monthly values for different tide-gauge stations. Besides the annual variation, there exists a quasi-periodic fluctuation of sea water temperature with a periods of 4–5 months in some part of the sea near our coast[2], so that a slow variation of the sea level may be influenced considerably by these causes.

Hence, in order that we may detect any actual vertical displacement of the local crust relative to the true mean sea level representing the geoid surface, the observed daily height must be corrected for the numerous disturbing factors. This is, indeed, a matter of considerable difficulty not only in practice but even in principle, as the meaning of the mean sea level and its relation to the geoid is still somewhat vague, especially when the problems are concerned with phenomena of short duration of time such as several days. For the present, we are obliged to be content with following the commonplace method of analysis by statistics of the specific influences of different assumed factors.

As to the effects of the barometric pressure and its spatial gradient, a special investigation has already been made by the present authors and the results are published in the Japanese Journal of Astronomy and Geophysics, Vol. 4, 1926, pp. 1–20. The theoretical barometer factor was there assumed and the mean annual effect of the gradient as a function of its magnitude and direction was deduced. This effect may in some extreme cases amount to 30-40 mm. Besides, the effect of the general barometric situation of the Northern Pacific was studied provisionally which was found to be generally small, but could amount to some 50 mm. in rare cases.

As to the effect of the variation in density of the sea water, rëliable data are scanty, especially as are needed here the daily values of the temperature and salinity. At the request of the authors, Prof. M. Tauti of the Imperial Japanese Fishery Institute, Tôkyô, kindly placed at our disposal the hydrographical data obtained at the four stations in the Prefecture of Miyazaki, i. e. Hososima, Miyanoura, Simanoura and Utimi. The data comprise the values of the temperature and salinity of the sea water at 0, 10 fathom and bottom respectively for the days of observation which are generally five in number for each month. Examining the data for the two years 1923 and 1924 it is found that, excepting the superficial layer, the range of the interdiurnal variation of the temperature within each month rarely amounts to 4°C. and that of the reduced density seldom to one promille. Though the observations are confined to the coastal stations only, we have no reason to expect that the variation will be greater than this in the sea off the coast. According to Prof. Nomitsu's investigation above cited, the annual or intermensual range of variation in sea level due to the variation in the density of the sea water is of the order of 20–50 cm. We can scarcely expect that the interdiurnal range within a month may ever attain this order of magnitude.

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[1] T. Nomitsu and M. Okamoto, Mem. Coll. Sci. Kyoto Imp. Univ., A. **10**, No. 3 (1927), 125.

[2] T. Terada, J. T. Liu and S. Yamaguti, Jap. J. Astr. Geophys,. **1** (1922), 47.

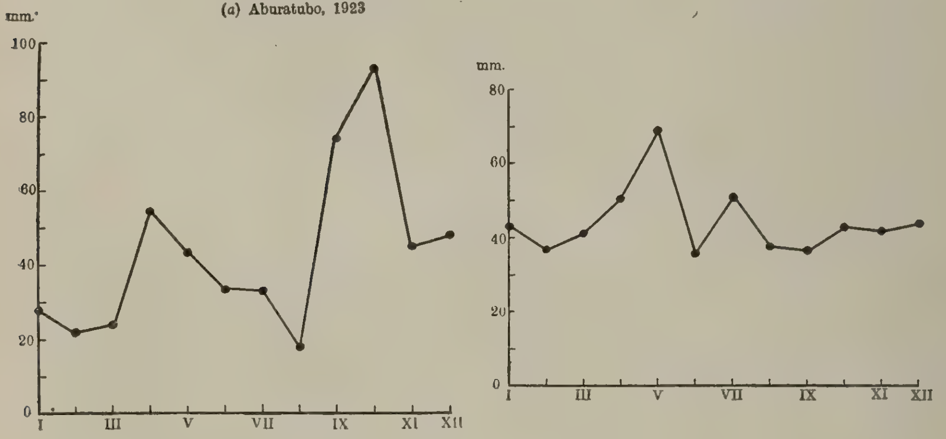
In order to see, however, if there could be detected some sensible correlation between the daily variation of sea level and that of the water temperature thus observed, the points were plotted with the former, for Hososima, corrected for the pressure and its gradient, as abscissa and the latter as ordinate; for the temperature data, those for the different stations were respectively taken and also the temperature was compared not only with the sea level of the corresponding day, but also respectively with the levels on the days before and after it. The points thus plotted are, however, hopelessly scattered in the area of the diagram and no trace of sensible correlation could be suspected.

We are, therefore, for the present at a loss to apply any systematic correction due to the density of the sea water, as we are concerned with the interdiurnal variation within a short epoch such as one or two months. According to Prof. Nomitsu's result, the annual range of variation due to the density is generally several times greater than that due to the barometric pressure. There are some reason to argue that the ratio of the two effects will be much different for the variation of shorter periods, as the effect of the barometric pressure is established rapidly, whereas the transfer of a large water mass may want a comparatively long time. We are, therefore, inclined to deny the possibility that the correction due to the density may ever attain here a magnitude greater than that due to the pressure and gradient.

Returning to our proper problem, our first task was to apply our assumed corrections due to the pressure and gradient to the daily values of the sea level for the four stations, Hososima, Aburatubo, Hanasaki and Wazima for 1923. For the first two stations, the data for 1924 were also taken and similarly corrected for the sake of comparison. Comparing the graph showing the daily course of the height of sea level thus corrected with that of the value directly observed, it appears clearly that the correction thus introduced is scarcely possible to produce any qualitative change in the general character of the curve. This will show that the assumed effect is utterly insufficient to explain the most remarkable fluctuation of the sea level as actually observed which may amount to 300 to 400 mm. within one month. The cause of such a great variation must be sought in another quarter.

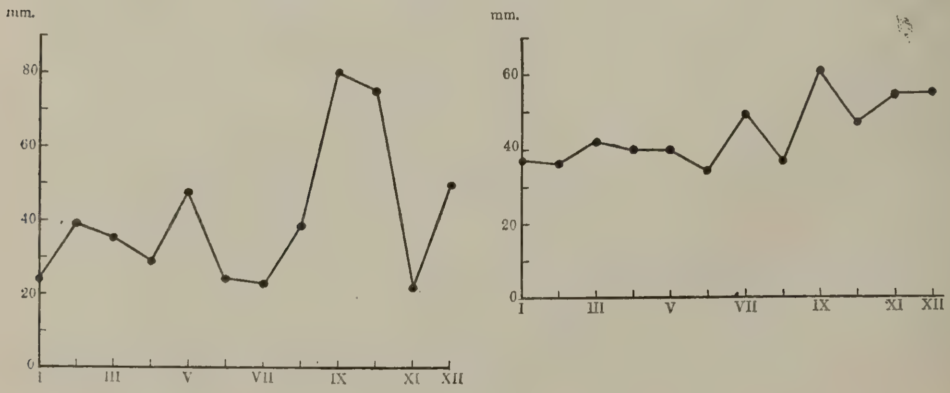
To obtain some convenient measure of the degree of fluctuation of the sea level, we took the absolute value of the deviation, $|\Delta L|$, of the daily value from the mean of each month and calculated the sum or the mean value of this $|\Delta L|$ for that month. The annual variation of this mean monthly value, $|\overline{\Delta L}|$, is shown in Fig. 1. It will be seen that

Fig 1.



(a) Aburatubo, 1923

(c) Hanasaki, 1923



(b) Hososima, 1923

(d) Wazima, 1923

$|\overline{\Delta L}|$ for the two months following the Great Earthquake, for Hososima and Aburatubo, are somewhat large compared with the others which are generally less than 70 mm. at most.

Considering that the above assumed corrections are derived from the statistical means in which some specific influences of abnormal barometric conditions may have been effaced, and also taking the fact into account that the said anomalous months were frequented by conspicuous cyclones, we proceeded to the following procedure, in order to see if this abnormal deviation could be explained by such a specific influence of cyclone. Thus, the daily absolute value of the deviation, $|\Delta b|$, of the barometric pressure[1] from the monthly mean value was taken, of which the sum or mean value was calculated. Then, the ratio $\sum|\Delta L|/\sum|\Delta b|$ was obtained for each month and graphically plotted in Fig. 2. Comparing Fig. 2 with Fig. 1, we may notice the followings. High values for IX and X, 1923, are still preserved in Fig. 2 and for Aburatubo, the maximum at IV in Fig. 1 has fallen into background in Fig. 2. At the same time, Wazima has revealed a large value at VIII which is

Fig. 2. (a) $\frac{|\Delta L|}{|\Delta b|}$, 1923

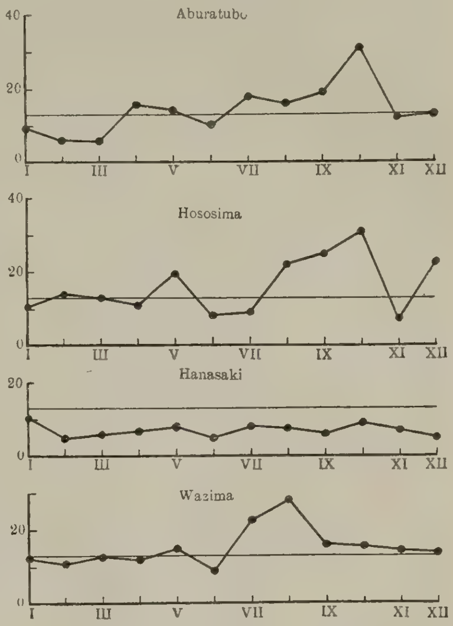
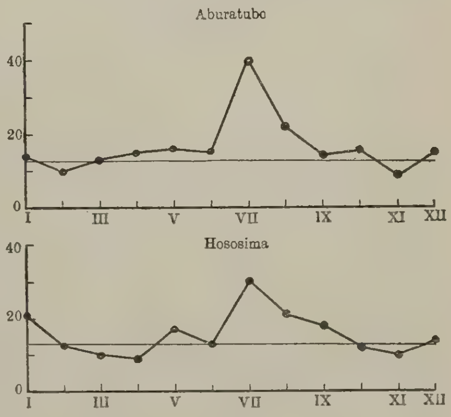


Fig. 2. (b) $\frac{|\Delta L|}{|\Delta b|}$, 1924



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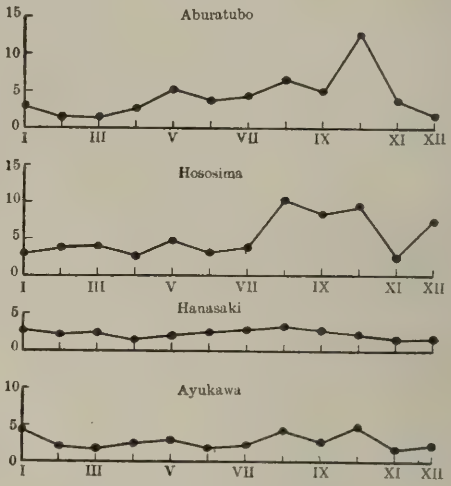
[1] For the barometric data, the following Meteorological Stations were taken: Hososima for Hososima, Yokosuka for Aburatubo, Kusiro for Hanasaki, and Kanazawa for Wazima.

comparable with those for Hososima and Aburatubo. Hanasaki is reduced to very flat curve. Moreover, for 1924, both Aburatubo and Hososima show very conspicuous high value in VII, though as a matter of fact the pressure variation was abnormally small in this month.

In Fig. 3 are shown the graphs for $\sum(\Delta L)^2/\sum(\Delta b)^2$ for 1923. Fig. 4 shows the comparison of the values of the same quantity for Aburatubo in 1923 and 1924.

Fig. 3. $\frac{\Sigma(\Delta L)^2}{\Sigma(\Delta b)^2}$, 1923

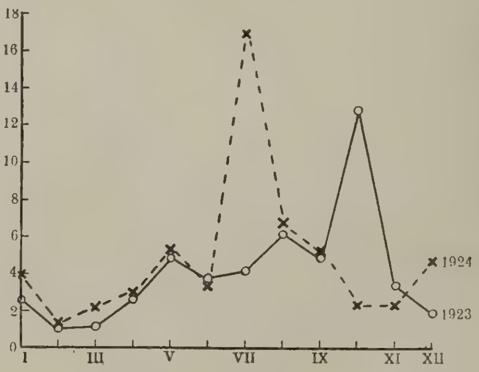


Though the results thus far obtained are not yet conclusive and a more systematic investigation is necessary in order to enable us to say anything definite, we may at least say that in October and probably also in September of 1923 the fluctuation of the sea level were unusually large and that such an anomaly is found also in another month of the next year apparently with no connection with a conspicuous phenomenon of the crust disturbance.[1]

Fig. 4. Aburatubo, $\frac{\Sigma(\Delta L)^2}{\Sigma(\Delta b)^2}$.

——o——: 1923

----×----: 1924



A plausible explanation of these abnormally large fluctuation in sea level may be sought partly in the fact that the amount of fluctuation of the barometric pressure over a wide area of the sea neighbouring the mareographic station may be considerably larger than at the land station of which

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1) A rather conspicuous earthquake is recorded on July 1, which originated off Hokkaidô to ESE of Erimozaki, but there is nothing to distinguish this shock with the others of the same order which occurred in the other months of the year.

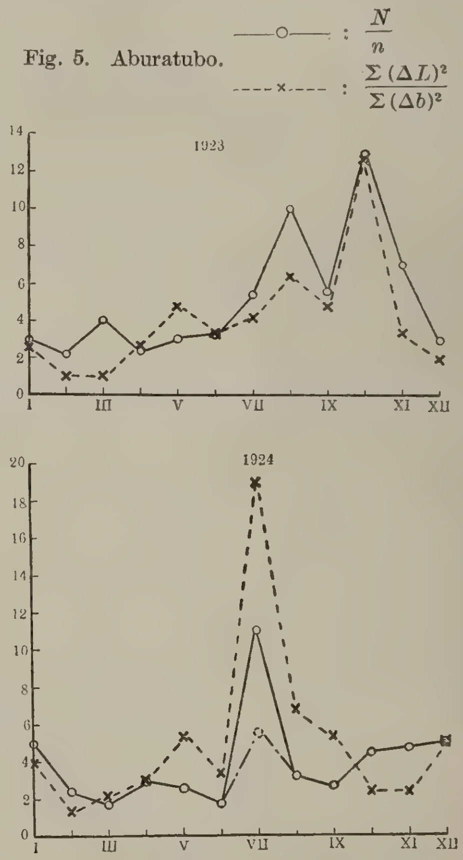
the barometric data are taken for the comparison. Such will be the case when in a certain month a large number of conspicuous cyclones prefer the routes remote from the coast. In such a month, the fluctuation in pressure recorded will be comparatively small, while the general sea level of the region frequented by the cyclones may be sensibly affected and the fluctuation will be felt in the coastal mareographic records. To test this idea, the monthly distribution of the cyclonic tracks was examined referring to the Charts of the tracks given in the Monthly Bulletin of the Imperial Marine Observatory, Kôbe, for the two years in question. The number, N, of the tracks falling within an area, 125°–145°E. and 10°–50°N., was counted for each month. Among these tracks those ones were selected which passed along the Pacific coast of Japan within a zone with some 500 km. of breadth; besides, those cyclones proceeding over land along the southern arc of the Islands were counted into the same group. The number of these particular tracks will be denoted by n. The values of N and n will be seen from Table I.

TABLE I.

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Total Number of Tracks, N.	4	5	4	7	7	4	2	1	2	1	1	4	1923
Number of Tracks along Pac. Coast, n.	12	11	16	17	21	13	11	10	11	13	9	12	
Ratio: N/n	3.0	2.2	4.0	2.4	3.0	3.3	5.5	10.0	5.5	13.0	9.0	3.0	
Total Number of Tracks, N.	2	4	7	5	6	9	1*	3	3	2	3	4	1924
Number of Tracks along Pac. Coast, n.	10	9	12	16	14	15	11	10	8	9	14	20	
Ratio: N/n	5.0	2.3	1.7	3.2	2.3	1.7	11.0	3.3	2.7	4.5	4.7	5.0	

There is, of course, same margin of ambiguity as to the value of n, since it is difficult to put a well defined boundary of the zone above mentioned. The general aspect of the qualitative relation to be inferred later will, however, not be modified, even if some alternative choice be made in the ambiguous cases. Only in the case with $n=1$, it makes a considerable difference whether it may be changed into $n=0$ or 2. Fortunately, in the present case no ambiguity was to be feared from this cause, except in VII, 1924. In this latter month, two tracks are recorded on the Pacific side, one of which took an abnormal course and proceeded towards NNW, i. e. nearly perpendicular to the Island Arc with a large velocity of progression. Another track originated, or rather was branched from the above one, in the sea off the coast of Sikoku and took also an abnormal retrograde path towards W. In this case, n may be 0, 1 or 2, according to our choice. But $n=2$ will be evidently too much, as the time during which the centre of cyclone was situated within the effective zone considered is too short; meanwhile, $n=0$ will be too small, as it will imply that there was no disturbance at all. By these reasons $n=1$ was provisionally taken.

Fig. 5. Aburatubo.



The ratio N/n was then calculated for each month, as given in the same table, and plotted in Fig. 5 by the full line curve. For the comparison, the value of $\sum(\Delta L)^2/\sum(\Delta b)^2$ from Fig. 4 is plotted by the dotted curve. A remarkable parallelism between the two curves will be evident.[1] Even if we take $n=2$[2] the maximum at July, 1924, will be still preserved.[3]

There is a probability that the value of N/n may be made to run more parallel to that of $\sum(\Delta L)^2/\sum(\Delta b)^2$, if we would introduce some suitable modification in the area of the chart to be taken into account and also in the limit of the zone within which the track is considered to have a vote on n. Moreover, it will be probably more reasonable to take, instead of n as above defined, the total sum of the intervals of time during which the cyclonic centres were loitering about in the distinguished zone. For the present, however, we will be satisfied with the knowledge of the qualitative trend of the relation and inquire after the physical meaning of the result here obtained.

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[1] It is by chance that the two curves happened to show nearly similar trend, by using the same scale for the ordinates. But it may turn out to be of some physical significance and we reserve this point for a future investigation.

[2] The point for $n=2$ is marked by broken circle in Fig. 5.

[3] In this month, there was recorded an abnormal cyclone which described a loop near Loochoo Isles and loitered about for six days in the Chinese Sea. This may contribute considerably to the effective value of N and increase N/n, even if we take $n=2$.

Comparing Fig. 5, N/n curve, with ΔL-curve in Fig. 1 or with $\sum|\Delta L|/\sum|\Delta b|$-curve in Fig. 2, it will be seen that the parallelism is not so good as in the case of Fig. 5. This will imply firstly that the theoretical barometrical correction is not adequate, but has been taken too small. This will already be seen from the fact that in Fig. 2 the value of $\sum|\Delta L|/\sum|\Delta b|$ is, on the average, of the order of 15 for Aburatubo, Hososima and Wazima, though it is less in the case of Hanasaki. This will mean that the actual barometric factor is to be taken at more than twice the theoretical value, a fact which agrees well with the result which was obtained by Saem. Nakamura$^{1)}$ and cited in our previous paper$^{2)}$.

Secondly, it may be inferred that it is mainly the larger fluctuations in sea level which are governed by the very cause as is here considered, i. e. the influence due to the cyclonic tracks frequenting the remote part of the sea.$^{3)}$

Thus far, we have arrived at the conclusion that the abnormally large fluctuations of the sea level here observed could be mainly explained by the effects of the cyclones which were raging on the sea so remote that they could not much affect the barometric pressure of the land stations. Our orginal aim to detect any real crustal movement which might have taken place, failed to be realized. Only, we have succeeded in disclosing, as a by-product, a new factor determining the fluctuation of sea level. Still, we are far from concluding that such a slow movement of the crust has *not* taken place. As already mentioned, the results of

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1) Jap. J. Astr. Geophys., **3** (1925), 115.

2) Loc. cit., p. 2; there, we have given some discussion on the possible origin of the abnormal value of the barometer factor. It was supposed that the variation of pressure is in some measure correlated statistically with that of the gradient. The same remark may be repeated here. The fact, however, that the value of $\Sigma|\Delta L|/\Sigma|\Delta b|$ in Wazima on the Japan Sea coast is not sensibly small compared with the values in Pacific coast seems to show that the influence of the local wind due to the land effect, cited in the previous paper, is not very conspicuous. Then, the more important cause of the high value of the barometer factor may be sought in some correlation existing between the local pressure and the general pressure distribution in the wide sea area which may be taken as zero level in considering the local fluctuation.

3) The mechanism by which such an effect may he brought about is still obscure and will be reserved for a future study.

the precise levelling made after the Kwantô Earthquake as well as the Tango Earthquake have revealed some infallible traces of the gradual movement of the crust even within an interval of a few months. Besides, the recent investigations by Dr. Ishimoto with his ingenius apparatus for measuring the tilting of the crust has revealed that the change in the inclination of the crust amounting to a few seconds within an interval of the order of several ten days is by no means rare. The difference in heights at the two ends of a line of 10 km. length due to a tilting of $4''$ is about 200 mm. If the tilting observed is not a merely local one limited to a very small extent, we may naturally expect a real[1] vertical movement of this order of magnitude at least sometimes, at some parts on the entire coast line.

On the other hand, we have some evidences[2] which seem to show that our earth is occasionally subjected to a change of considerable amount in its internal mass distribution such as to affect even its period of daily rotation about its axis. Admitting such be actually the case, it will be no wonder if some local portions of the crust may be executing a slow pulsatory motion of the above said order of magnitude. It seems, indeed, that we must abandon our traditional conception of *terra firma* and resume rather the idea expressed in the Japanese mythology as to the state of lands in its day of beginning.[2]

At any rate, we must not forget that there exists yet no positive evidence which may disprove beyond doubt the possibility of such a slow pulsatory motion of the crust relative to the geoid, which is nothing more than an ideal *mean* equipotential surface derived from the meagre gravitational and geodetic data obtained under the tacit assumption of its perfect invariability.

The present report may rather be regarded as an unsuccessful outcome of an attempt to detect this possible crustal disturbance, owing to the insufficiency of our knowledge regarding the influences of meteorological elements upon the sea level. A step towards the elucidation of these effect has, however, been taken. We may hope, some day will come when the suspected vertical movement, if any, may be disclosed by

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1) I. e. aganist the geoid.

2) For example: W. de Sitter, "On the Rotation of the Earth and Astronomical Time," Nature, **121** (1928), Supplement, 99. See also: T. Terada and N. Miyabe," On a Long Period Fluctuation in Latitude of the Macroseismic Zone of the Earth," Proc. Imp. Acad., **3** (1927), 275.

3) See Koziki and Nihonsyoki. An analogy of snow floating on water is mentioned in a version quoted in the latter book.

means of the analysis of mareographic records, provided the necessary meteorological data may be available, over a wide extent of the ocean.

A further investigation of the effect of cyclone on the sea level is now in progress in the line suggested by the result of the above preliminary study.

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IMPERIAL EARTHQUAKE INVESTIGATION COMMITTEE

Vol. XI No. 4

Page

The Imperial Japanese Military Land Survey:
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TOKYO

June, 1930

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第十一巻 第四號

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Page

THE IMPERIAL JAPANESE MILITARY LAND SURVEY: Re-survey of the Kwanto District after the Great Earthquake of 1923 .... 1—6

TOKYO

June, 1930

Re-survey of the Kwantô District after the Great Earthquake of 1923.

By

Rikuti Sokuryobu.

(The Imperial Japanese Military Land Survey.)

Soon after the great earthquake of 1923, the Military Land Survey re-serveyed the precise levelling routes in the environs of Tôkyô and along the coasts of the Bôsô Peninsula and of Sagami Province.

The result showed remarkable changes in the elevation of the land, and it was made clear that the re-survey should not be restricted to a narrow area. It was then decided to re-measure the whole Kwantô district, and, with an appropriate grant for the purpose, work was started at once. It is now eight years since the survey was begun; the field work was concluded in 1927. Apart from its practical values, the results of the survey should provide important material for the study of surface movements of the earth. Several reports in the Japanese language have already been published in regard to the work, and the following is merely a resume of these reports.

I. The Sagamino Base-Line.

The Sagamino Base Line is in the Kôza District, one of the most devastated regions in Kanagawa Prefecture. Re-measurement of this line began early in May 1924 and lasted two months. The apparatus used in the work was 25-metre invar wires and tapes, the lengths of which were standardized both before and after field operations by comparison with the 25-metre base line of the Japanese Geodetic Commission at the Tôkyô Astronomical Observatory. The standardized lengths of the wires and tapes are as follows:—

No. of wire and tape	Length at 15° C, under a weight of 10 kg.	Mean error	Coefficients of expansion	
	m mm	mm	α	β
663 (Carpentier)	25 − 0.01	±0.005	+0.000000060	−0.00000000003
665 ”	−0.95	±0.007	+0.000000060	−0.00000000003
666 ”	+0.07	±0.007	+0.000000060	−0.00000000003
12644 (Agar Bough)	−0.13	±0.006	+0.000000856	−0.00000000209
12645 ”	−0.86	±0.005	+0.000000928	−0.00000000451

A small part of the base field is forest land, while the remainder is cultivated, so that the ground surface is fairly even. From a point in the middle the base-line was divided into a southern and a northern section. Both of these sections were measured in opposite directions, that is backward and forward, five times. The results obtained are tabulated below:—

No. of wire and tape	Southern half section		Northern half section	
	Mean of the back and forth meas'nts	Residual	Mean of the back and forth meas'nts	Residual
663	m mm 2610+94.12	mm +0.32	m mm 2600+188.17	mm −0.27
665	95.56	−1.12	189.54	−1.64
666	92.39	+2.05	187.09	+0.81
12644	92.51	+1.93	184.66	+3.24
12645	97.62	−3.18	190.06	−2.16
Mean length..................	m mm 2610+94.44	mm ±0.664	m mm 2600+187.90	mm ±0.650
Reduction to sea level ...	mm −32.62		mm − 37.26	
Resultant length of base...	m mm 2610+61.82	mm ±0.664	m mm 2600+150.64	mm ±0.650

Total Length of Base $=\overset{m}{5210}+\overset{mm}{212.5}\pm\overset{mm}{0.93}$.

The errors given in the table are the probable errors arising from that of measurement only. Its ratio to the total base length is about 1/5600000.

Assuming that p. e. arising from other sources, such as those in the standard base-line, measuring scales, alignment of the base-line, etc., to be independent, the p. e. of this base-line is 4.84 mm. and 1/1076000 of the total length.

As shown in the following table, the Sagamino base was measured several times after its establishment. Comparing the new result with any one of the old, it is evident that this base had lengthened after the 1923 earthquake.

No.	Year	Apparatus used	Length of base-line	Office in charge
1	1882	4 metres Hilgard base apparatus	m mm mm 5210− 30.4±3.07	Military Land Survey
2	1892	100 m. steel tapes	5210+ 12.9±1.09	Geodetic Commission
3	1910	25 m. invar scales	5210− 33.1±1.14	Geodetic Commission
4	1924	25 m. invar scales	5210+212.5±0.93	Military Land Survey

The length of the Guillaume apparatus which was used on the present occasion to determine the standard base-line, was examined in 1916. This apparatus, however, was restandardized in 1926 by comparison with standard Length No. 20.

The following is the value of Guillaume's apparatus as determined in 1916 and 1926.

1916	$5^{m}+0^{mm}.0638$
1926	$5^{m}+0^{mm}.0688$

If the value of Guillaume's apparatus of 1926 were adopted, the length of Sagamino base would become longer by 5.2 mm.

II. Primary Triangulation.

Re-observations of the primary points were carried out over an area of about 17,000 sq. kms., enclosed by the lines connecting the principal points Manzirodake, Kenasiyama, Kokusidake, Dôhirayama, Teruisiyama, Tukubasan and Rokudizô, in the marginal regions of which the influence of the earthquake was assumed to be almost nil (see plates I and II).

The field work, which began early in May, 1924, continued until the middle of October, 1925. The horizontal angles were observed with a 27 cm. Carl Bamberg theodolite and all pointings were made to a heliograph or acetylene lamp. The old survey was made between the interval 1884–1899. The instruments used, and the methods of observation, in the old and the new surveys were identical.

In appended tables I and II, adjusted angles, error of closure and sides of each triangle are shown with the old and new compared. In appended table III and plate III, comparison of the new and old geographic positions of the primary points are made under the assumption, (1) that the geographic position of Teruisiyama and its azimuth to Tukubasan have not changed and, (2) that the geographic position of Kokusidake and its azimuth to Dôhirayama have not changed.

The following is a brief description of the precision of the old and new results :—

1. Base net.

Denoting the closing error of triangle and the number of triangles by w and n, respectively, then the mean error of a single angle is

$$m_1=\sqrt{\frac{[w\cdot w]}{3n}}=\pm 0''.605\text{..........................old,}$$

$$m_1=\sqrt{\frac{[w\cdot w]}{3n}}=\pm 0''.598\text{..........................new.}$$

Mean error of a single direction with unit weight is

$$m_0=\sqrt{\frac{[p\delta\delta]}{r}}=\pm 2''.050 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{old},$$

$$m_0=\sqrt{\frac{[p\delta\delta]}{r}}=\pm 3''.316 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{new},$$

where $[p\delta\delta]$ is the sum of the squares of the residuals derived from adjustment, and r is the number of condition equations.

Assuming the weight of observation to be 24.5, as it was generally 24 or 25 in this survey, the mean error of a single angle is

$$m_1'=\sqrt{\frac{2m_0^2}{24.5}}=\pm 0''.585\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{old},$$

$$m_1'=\sqrt{\frac{2m_0^2}{24.5}}=\pm 0''.947\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{new}.$$

Using m_0 and p, the weight of adjusted value, the precision of the last expanded side of the base net is

$$m_l=\frac{m_0}{\sqrt{p}}=\pm 19.7 \text{ (to seven places of logarithms)}$$
$$=\pm 0^{\text{m}}.346\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{old},$$

$$m_l=\frac{m_0}{\sqrt{p}}=\pm 31.4 \text{ (to seven places of logarithms)}$$
$$=\pm 0^{\text{m}}.551\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{new}.$$

Moreover, if the error of base line is taken into consideration, mean error of the last expanded side is

$$m_l'=\pm 0^{\text{m}}.352 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{old},$$
$$m_l'=\pm 0^{\text{m}}.551 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{new}.$$

And from which the mean error of the change of the last expanded side is $0^{\text{m}}.7$, approximately.

2. *Principal point.*

Mean error of a single angle is

$$m_1=\sqrt{\frac{[ww]}{3n}}=\pm 1''.156\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{old},$$
$$=\pm 0''.682\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{new},$$

and mean error of a single angle obtained by adjustment is

$$m_1'=\sqrt{\frac{[p\delta\delta]}{r}}\sqrt{\frac{2}{p}}=\pm 1''.028 \;\ldots\ldots\ldots\ldots\ldots\ldots\text{old},$$
$$=\pm 1''.183 \;\ldots\ldots\ldots\ldots\ldots\ldots\text{new}.$$

3. Supplementary point.

Mean error of a single angle is

$$m_1 = \sqrt{\frac{[ww]}{3n}} = \pm 0''.826 \text{..........................old,}$$
$$= \pm 1''.172 \text{..........................new.}$$

III. Secondary and Tertiary Triangulations.

Although the Secondary and Tertiary triangulations were carried out only in the severely shocked regions, the area covered amounted to about 8000 sq. km. (see plate I).

The horizontal and vertical angles were observed by 21 cm. and 14 cm. Carl Bamberg theodolites. The mean closing error in the secondary triangulation is $\pm 1''.30$ and that in the Tertiary Triangulation $\pm 2''.38$.

Tables IV and V appended show the changes in positions of the secondary and tertiary trigonometrical points, assuming that the primary points Manzirodake, Kenasiyama, Kokusidake, Dôhirayama, Teruisiyama, Tukubasan and Rokudizô have not change their positions during the periods before and after the 1923 earthquake.

The changes in elevation of the trigonometrical points, which were obtained by trigonometrical levelling, are shown on Plate VII.

IV. Precise Levelling.

The re-observed route of the precise levelling is shown in Plates I and VII. Its total length is about 2,622 kms. This work, which began at the end of Sept. of 1923, did not finish until the end of March, 1927.

The observations were carried out chiefly with a Carl Zeiss No. III type level with plane mirror, and staves with invar bands. The backward direction measurement on each section was made with every possible care under different atmospheric conditions from those that prevailed during the forward measurements. On every 2 km. section between successive bench-marks, in which the forward and backward measurements differed by more than 3 mm., the measurements were repeated until they came within the permissible difference. The error of the circuit closure was limited to $1^{\text{mm}}.5\sqrt{K}$ (in which K is the length of levelling circuit in kilometres).

The methods used in the new survey in nowise differed from those used in the old survey made during 1884–1898. The instruments used in the old survey were Carl Bamberg levels and staves.

The change of Standard Datum for geodetic levelling was tested, (1) by comparing the heights of standard datum points above mean sea level both before and after the earthquake, and (2) by the result of precise levellings between standard datum point and bench marks situated in regions unaffected by the earthquake. In consequence of the results, the standard datum was corrected by –86 mm.

Plates Nos. VI and VII give comparisons of old and new results derived by the same method of adjustment. Plates Nos. IV and V show the closing errors of levelling nets and mean errors per kilometre.

Table I.— Comparison of angles and closing errors, new and old triangulation

Base Net						
Point	名　稱	Adjusted spherical angles		Differences	Closing errors	
		Old	New	New—Old	Old	New
		° ′ ″	″	″	″	″
Tobinoo Y.	鳶尾山	30 54 09,962	12,382	+ 2,420	+ 1,118	− 1,199
Zama M.	座間村	51 54 63,011	54,306	− 8,705		
Simomizo M.	下溝村	97 10 47,132	53,418	+ 6,286		
Nagatuda M.	長津田村	45 19 31,406	36,997	+ 5,591	− 0,617	− 0,348
Simomizo M.	下溝村	43 49 62,038	52,810	− 9,228		
Zama M.	座間村	90 50 26,623	30,260	+ 3,637		
Nagatuda M.	長津田村	24 57 32,840	37,822	+ 4,982	+ 0,920	+ 0,650
Tobinoo Y.	鳶尾山	12 16 57,606	57,692	+ 0,086		
Zama M.	座間村	142 45 29,634	24,566	− 5,068		
Nagatuda M.	長津田村	20 21 58,566	59,175	+ 0,609	− 0,420	− 2,198
Simomizo M.	下溝村	141 00 49,170	46,228	− 2,942		
Tobinoo Y.	鳶尾山	18 37 12,356	14,690	+ 2,334		
Renkôzi M.	連光寺村	49 32 05,849	09,874	+ 4,025	+ 0,289	+ 0,340
Tobinoo Y.	鳶尾山	44 32 55,626	63,738	+ 8,112		
Nagatuda M.	長津田村	85 54 59,011	46,875	− 12,136		
Renkôzi M.	連光寺村	29 20 02,653	01,068	− 1,585	+ 1,522	+ 0,423
Sengen Y.	淺間山	14 25 53,507	55,280	+ 1,773		
Nagatuda M.	長津田村	136 14 04,451	04,263	− 0,188		
Sengen Y.	淺間山	18 48 52,475	55,122	+ 2,647	− 1,327	− 0,702
Renkôzi M.	連光寺村	20 12 03,196	08,806	+ 5,610		
Tobinoo Y.	鳶尾山	140 58 64,943	56,687	− 8,256		
Tanzawa Y.	丹澤山	83 32 26,450	22,518	− 3,932	− 0,711	+ 0,956
Sengen Y.	淺間山	60 47 41,183	34,907	− 6,276		
Renkôzi M.	連光寺村	35 39 54,143	64,350	+ 10,207		
Kanô Z.	鹿野山	35 48 14,234	13,878	− 0,356	+ 1,333	− 1,370
Renkôzi M.	連光寺村	69 07 24,371	14,351	− 10,020		
Sengen Y.	淺間村	75 04 26,747	37,122	+ 10,375		
Kanô Z.	鹿野山	24 21 35,601	33,460	− 2,141	− 1,078	+ 0,796
Renkôzi M.	連光寺村	104 47 18,514	18,701	+ 0,187		
Tanzawa Y.	丹澤山	50 51 10,749	12,703	+ 1,954		
Kanô Z.	鹿野山	11 26 38,633	40,418	+ 1,785	+ 1,700	− 1,210
Tanzawa Y.	丹澤山	32 41 15,701	09,815	− 5,886		
Sengen Y.	淺間山	135 52 07,930	12,029	+ 4,099		
Sengen Y.	淺間山	33 14 45,982	50,402	+ 4,420	− 0,095	− 0.619
Nagatuda M.	長津田村	50 19 05,440	17,388	+ 11,948		
Tobinoo Y.	鳶尾山	96 25 69,317	52,949	− 16,368		
Mean error of a single angle (一角ノ中等誤差) $= m = \sqrt{\frac{[\omega\omega]}{3n}} =$					″ ± 0,605	″ ± 0,598

Table I.—— Comparison of angles and closing errors, new and old triangulation ——contd.

Principal Point

Point	名　稱	Adjusted spherical angle		Differece	Closing errors	
		Old	New	New—Old	Old	New
		° ′ ″	″	″	″	″
Tokyô.	東　京	90 30 80,282	10,092	+ 1,810	− 1,312	− 0,285
Tanzawa Y.	丹澤山	39 50 09,616	13,229	+ 3,613		
Kanô Z.	鹿野山	47 39 49,072	43,649	− 5,423		
Dôhira Y.	堂平山	54 49 17,902	13,041	− 4,861	− 2,428	− 0.365
Tanzawa Y.	丹澤山	66 11 26,616	28,502	+ 1,886		
Tôkyô.	東　京	58 59 23,205	26,180	+ 2,975		
Kokusi D. II	國師岳II	64 32 32,493	32,381	− 0,112	+ 0,703	+ 0,117
Tanzawa Y.	丹澤山	40 56 10,575	05,211	− 5,364		
Dôhira Y.	堂平山	74 31 23,122	28,599	+ 5,477		
Kenasi Y.	毛無山	66 03 59,528	65,278	+ 5,750	+ 1,870	+ 1,603
Tazawa Y.	丹澤山	58 00 57,797	52,646	− 5,151		
Kokusi D. II	國師岳II	55 55 10,425	09,827	− 0,598		
Manziro D.	萬城岳	46 39 04,499	08,391	+ 3,892	+ 0,091	− 0,347
Tanzawa Y.	丹澤山	71 12 36,138	39,144	+ 3,006		
Kenasi Y.	毛無山	62 08 28,897	21,997	− 6,900		
Bôdai S.	房大山	54 16 09,860	1,837	− 8,023	− 2,761	+ 1,322
Tanzawa Y.	丹澤山	57 06 37,041	38,556	+ 1,515		
Manziro D.	萬城岳	68 37 24,890	31,400	+ 6,510		
Kanô Z.	鹿野山	82 07 48,818	48,379	− 0,439	+ 3,033	− 2,332
Tanzawa Y.	丹澤山	26 41 62,217	62,712	+ 0,495		
Bôdai S.	房大山	71 10 15,881	15,825	− 0,056		
Rokudizô.	六地藏	72 24 16,008	22,565	+ 6,557	+ 2,499	+ 1,118
Tôkyô	東　京	37 31 12,762	11,896	− 0,866		
Kanô Z.	鹿野山	70 04 34,862	29,171	− 5,691		
Tukuba S.	筑波山	33 40 04,570	05,028	+ 0,458	+ 1,172	− 1,099
Tôkyô.	東　京	91 22 06,293	05,497	− 0,796		
Rokudizo.	六地藏	54 57 57,822	58,159	+ 0,337		
Teruisi Y,	晃石山	64 37 16,965	16,930	− 0,035	片向方	片方向
Tôkyô.	東　京	31 52 51,876	50,385	− 1,491		
Tukuba S.	筑波山	83 29 58,610	60,136	+ 1,526		
Dôhira Y.	堂平山	79 45 27,432	29,404	+ 1,972	片方向	片方向
Tôkyô	東　京	47 44 17,583	15,949	− 1,634		
Teruisi Y.	晃石山	52 30 24,243	23,905	− 0,338		
Teruisi Y.	晃石山	117 07 41,208	40,835	− 0,373	− 1,653	+ 0,268
Dôhira Y.	堂　山	79 45 27,432	29,404	+ 1,972		
Tôkyô.	東平京	79 37 09,458	06,335	− 3,123		
Tukuba S.	筑波山	83 29 58,610	60,136	+ 1,526		
Mean error of a single angle (一角ノ中等誤差) $= m = \sqrt{\frac{[\omega\omega]}{3n}} =$					± 1,156	± 0,682

Table I.—— Comparison of angles and closing errors, new and old triangulation——contd.

Supplementary points						
Point	名稱	Adjusted spherical angle		Differences	Closing errors	
		Old	New	New−Old	Old	New
		° ′ ″	″	″	″	″
Takane.	高根	120 08 00,93	05,48	+ 4,55	− 3,21	+ 1,84
Dôhira Y.	堂平山	34 13 42,21	39,13	− 3,08		
Tanzawa Y.	丹澤山	25 38 19,35	17,88	− 1,47		
Takane.	高根	57 36 07,03	01,18	− 5,85	− 0,87	− 2,22
Tanzawa Y.	丹澤山	29 32 05,96	10,88	+ 4,92		
Renkôzi M.	連光寺村	92 51 48,57	49,50	+ 0,93		
Kumotori Y.	雲取山	134 40 37,78	38,09	+ 0,31	− 1,02	− 3,59
Kokusi D. II	國師岳II	31 48 57,80	58,36	+ 0,56		
Tanzawa Y.	丹澤山	13 30 26,17	25,31	− 0,86		
Kumotori Y.	雲取山	52 23 14,39	11,51	− 2,88	− 0,44	+ 3,92
Tanzawa Y.	丹澤山	53 03 63,76	57,79	− 5,97		
Takane.	高根	74 32 45,49	54,34	+ 8,85		
Kumotori Y.	雲取山	49 24 47,97	52,36	+ 4,39	− 1,49	− 2,13
Takane.	高根	45 35 15,44	11,14	− 4,30		
Dôhira Y.	堂平山	84 59 58.67	58,58	− 0,09		
Kumotori Y.	雲取山	123 31 19,86	18,04	− 1,82	+ 0,44	+ 3,75
Dôhira Y.	堂平山	23 45 06,66	09,15	+ 2,49		
Kokusi D. II	國師岳II	32 43 34,69	34,02	− 0,67		
Koganezawa Y,	小金澤山	93 02 13,13	16,79	+ 3,66	− 1,21	+ 0,55
Kenasi Y.	毛無山	39 26 12,81	14,63	+ 1,82		
Tanzawa Y.	丹澤山	47 31 37,95	32,47	− 5,48		
Koganezawa Y.	小金澤山	108 30 07,21	10,99	+ 3,78	+ 1,58	− 2,35
Tanzawa Y.	丹澤山	23 59 46,01	45,48	− 0,53		
Kumotori Y.	雲取山	47 30 08,53	05,28	− 3,25		
Gosyôtai Y.	御正體山	86 27 29,41	15,94	−13,47	− 2,03	+ 0,93
Koganezawa Y.	小金澤山	60 04 40,77	50,99	+10,22		
Kenasi Y.	毛無山	33 27 51,99	55,23	+03,24		
Gosyôtai Y.	御正體山	109 57 26,78	37,39	−10,61	+ 1,07	+ 2,07
Tanzawa Y.	丹澤山	37 04 62,02	57,98	− 4,04		
Koganezawa Y.	小金澤山	32 57 32,36	25,80	− 6,56		
Hôten M.	法典村	36 01 52,08	49,44	− 2,64	− 1,20	+ 0,00
Kanô Z.	鹿野山	45 19 57,12	53,15	− 3,97		
Rokudizo.	六地藏	98 38 13,75	20,36	+ 6,61		
Hôten M.	法典村	132 37 54,96	53,94	− 1,02	+ 1,76	+ 1,17
Rokudizô.	六地藏	28 43 60,08	60,37	+ 0,29		
Tukuba S.	筑波山	18 38 08,96	09,70	+ 0,74		
Hôten M.	法典村	122 56 04,47	06,58	+ 2,11	− 1,05	− 1,92
Tukuba S.	筑波山	15 01 55,61	55,33	− 0,28		
Tôkyo.	東京	42 02 02,58	00,74	− 1,84		
Hôten M.	法典村	68 24 08,49	10,04	+ 1,55	+ 2,03	− 1,11
Tôkyô.	東京	86 51 16,47	16,66	+ 0,19		
Kanô Z.	鹿野山	24 44 37,74	36,02	− 1,72		

Table I.—— Comparison of angles and closing errors, new and old triangulation——contd.

Supplementary points						
Point	名稱	Adjusted spherical angle		Differences	Closing errors	
		Old	New	New–Old	Old	New
		° ′ ″	″	″	″	″
Hôten M.	法典村	104 25 60,57	59,48	− 1,09		
Tôkyô.	東京	49 20 03,71	04,76	+ 1,05	− 1,64	+ 0,01
Rokudizô.	六地藏	26 13 57,74	57,79	+ 0,05		
Hutago Y.	二子山	62 17 32,96	21,34	− 11,62		
Renkôzi M.	連光寺村	40 25 35,25	26,84	− 8,41	+ 3,25	+ 2,00
Sengen Y.	淺間山	77 16 54,26	74,29	+ 20,03		
Hutago Y.	二子山	113 37 55,90	50,84	− 5,06		
Kanô Z.	鹿野山	37 40 17,92	25,20	+ 7,28	+ 0,20	− 5,69
Renkôzi M.	連光寺村	28 41 49,21	46,99	− 2,22		
Kuranami.	藏浪	53 48 58,43	54,02	− 4,41		
Hutago Y.	二子山	32 30 51,06	55,50	+ 4,44	+ 0,38	− 0,38
Kanô Z.	鹿野山	93 40 12,23	12,20	− 0,03		
Kuranami.	藏浪	100 22 57,21	53,97	− 3,24		
Kanô Z.	鹿野山	37 22 53,99	52,58	− 1,41	+ 0,31	− 0,54
Rokudizô.	六地藏	42 14 09,83	14,48	+ 4,65		
Kuranami.	藏浪	92 56 49,24	48,51	− 0,73		
Rokudizô.	六地藏	56 24 03,92	05,88	+ 1,96	− 0,05	− 0,40
Hôten M.	法典村	30 39 08,37	07,14	− 1,23		
Kaminumabe.	上沼部	94 32 21,74	31,32	+ 9,58		
Renkôdi M.	連光寺村	58 38 11,57	08,25	− 3,32	− 1,85	+ 1,08
Hutago Y.	二子山	26 49 28,32	22,06	− 6,26		
Kaminumabe.	上沼部	69 50 32,90	26,48	− 6,42		
Hutago Y.	二子山	54 17 36,52	33,28	− 3.24	+ 0,28	− 3,03
Kuranami.	藏浪	55 51 53,42	63,08	+ 9,66		
Kaminumabe.	上沼部	57 02 57,93	61,49	+ 3,56		
Kuranami.	藏浪	56 59 21,70	20,42	− 1,28	+ 0.43	+ 0,89
Hôten M.	法典村	65 57 42,67	40,38	− 2,29		
Kaminumabe.	上沼部	42 06 33,12	40,69	+ 7,57		
Renkôdi M.	連光寺村	69 43 44,10	33,86	− 10,24	+ 0,57	+ 1,37
Nagatuda M.	長津田村	68 09 43,36	46,03	+ 2,67		
Tokumaru.	德丸	49 55 29,27	25,97	− 3,30		
Renkôdi M.	連光寺村	54 43 53,74	58,83	+ 5,09	− 2,32	− 0,35
Kaminumabe.	上沼部	75 20 37,88	36,09	− 1,79		
Tokumaru.	德丸	78 52 45,78	46,86	+ 1,08		
Kaminumabe.	上沼部	63 13 29,55	24,62	− 4,93	+ 1,16	− 0,90
Hôten M.	法典村	37 53 46,06	49,92	+ 3,86		
Hongô.	本鄉	68 17 47,82	53,26	+ 5,44		
Takane.	高根	66 36 01,21	59,76	− 1,45	− 0,64	− 3,34
Renkôzi M.	連光寺村	45 06 11,60	07,61	− 3,99		
Hongô.	本鄉	94 10 44,75	39,06	− 5,69		
Renkôzi M.	連光寺村	32 34 25,41	24,13	− 1,28	− 0,53	+ 4,44
Tokumaru.	德丸	53 14 50,44	57,41	+ 6,97		

Table I.—— Comparison of angles and closing errors, new and old triangulation——contd.

Supplementary points						
Point	名稱	Adjusted spherical angle		Differences	Closing errorss	
		Old	New	New–Old	Old	New
		° ′ ″	″	″	″	″
Mineoka	峰岡	150 01 24,42	29,33	+ 4,91	+ 0,33	– 1,53
Kanô Z.	鹿野山	47 28 41,00	43,29	+ 2,29		
Bôdai S.	房大山	27 29 55,75	48,54	– 7,21		
Mineoka..	峰岡	44 30 01,87	59,12	– 2,75	+ 1,69	+ 0,39
Rokudizô.	六地藏	22 50 53,14	46,63	– 6,51		
Kanô Z.	鹿野山	112 39 06,25	15,51	+ 9,26		
Nokogiri Y.	鋸山	102 27 45,34	30,02	– 15,32	– 1,59	+ 0,94
Kanô Z.	鹿野山	50 38 16,02	23,10	+ 7,08		
Hutago Y.	二子山	26 53 59,58	67,82	+ 8,24		
Nokogiri Y.	鋸山	86 03 28,27	58,62	+ 30,35	+ 1,02	+ 2,62
Bôdai S.	房大山	39 20 56,59	42,02	– 14,57		
Mineoka.	峰岡	54 35 36,14	20,36	– 15,78		
Nokogiri Y.	鋸山	63 54 40,79	35,00	– 5,79	– 2,01	– 0,04
Mineoka.	峰岡	50 25 48,28	68,97	+ 20,69		
Kanô Z.	鹿野山	65 39 31,51	16,61	– 14,90		
Ookawa.	大川	58 15 57,72	82,27	+ 24,55	+ 1,58	+ 2,71
Nokogiri Y.	鋸山	33 50 51,25	63,31	+ 12,06		
Bôdai S.	房大山	87 52 71,88	35,27	– 36,61		
Ookawa.	大川	41 21 33,06	40,45	+ 7,39	– 0,86	+ 0,56
Mineoka.	峰岡	86 25 50,85	25,17	– 25,68		
Nokogiri Y.	鋸山	52 12 37,02	55,31	+ 18,29		
Ookawa.	大川	99 37 30,78	62,72	+ 31,94	– 0,30	+ 0,65
Mineoka.	峰岡	31 50 14,71	04,81	– 9,90		
Bôdai S.	房大山	48 31 75,29	53,25	– 22,04		
Asitaka Y.	愛鷹山	92 03 06,06	11,69	+ 5,63	0,00	+ 3,21
Tanzawa Y.	丹澤山	36 49 19,00	19,76	+ 0,76		
Kenasi Y.	毛無山	51 07 38,81	32,42	– 6,39		
Asitaka Y.	愛鷹山	108 05 16,98	11,56	– 5,42	– 3,11	– 1,17
Manziro D.	萬城岳	37 31 30,32	33,50	+ 3,18		
Tanzawa Y.	丹澤山	34 23 17,14	19,39	+ 2,25		
Asitaka Y.	愛鷹山	159 51 36,96	36,75	– 0,21	0,00	– 2,39
Kenasi Y.	毛無山	11 00 50,08	49,58	– 0,50		
Manziro D.	萬城岳	09 07 34,18	34,90	+ 0,72		
Kamuriga T.	冠ヶ岳	126 55 48,10	45,54	– 2,56	0,00	+ 0,98
Tanzawa Y.	丹澤山	20 50 13,62	15,76	+ 2,14		
Asitaka Y.	愛鷹山	32 13 59,48	59,90	+ 0,42		
Kamuriga T.	冠ヶ岳	76 20 53,87	56,91	+ 3,04	– 2,51	– 0,30
Asitaka Y.	愛鷹山	75 51 17,50	11,66	– 5,84		
Manziro D.	萬城岳	27 47 50,65	53,45	+ 2,80		
Kamuriga T.	冠ヶ岳	156 43 18,03	17,55	– 0,48	– 1,32	– 1,85
Manziro D.	萬城岳	09 43 39,67	40,04	+ 0,37		
Tanzawa Y.	丹澤山	13 33 03,52	03,63	+ 0,11		

Table I.—— Comparison of angles and closing errors, new and old triangulation——contd.

Supplementary points

Point	名稱	Adjusted spherical angle		Differences	Closing errors	
		Old	New	New – Old	Old	New
		° ′ ″	″	″	″	″
Ootani.	大谷	66 13 51,44	48,27	– 3,17	+ 0,23	+ 1,16
Rokudizô.	六地藏	59 42 03,88	05,16	+ 1,28		
Kuranami.	藏浪	54 04 05,39	07,28	+ 1,89		
Ootani.	大谷	77 25 03,89	13,19	+ 9,30	– 0,42	– 0,26
Kuranami.	藏浪	46 18 51,82	46,69	– 5,13		
Kanô Z.	鹿野山	56 16 05,02	00,85	– 4,17		
Ootani.	大谷	45 31 34,80	23,46	– 11,34	+ 1,53	– 0,55
Kanô Z.	鹿野山	93 45 55,22	67,24	+ 12,02		
Mineoka.	峰岡	40 42 30,67	29,99	– 00,68		
Ohotani.	大谷	143 38 55,33	61,46	+ 6,13	– 0,49	+ 1,45
Rokudizo.	六地藏	17 27 54,05	50,68	– 3,37		
Kanô Z.	鹿野山	18 53 11,03	08,27	– 2,76		
Nonoduka.	野々塚	108 25 17,14	13,38	– 3,76	– 1,37	+ 2,80
Rokudizo.	六地藏	28 30 58,18	57,98	– 0,20		
Mineoka.	峰岡	43 03 46,15	50,11	+ 3,96		
Nonoduka.	野々塚	22 22 49,12	45,73	– 3,39	+ 2,44	– 0,16
Mineoka	峰岡	135 34 32,61	36,30	+ 3,69		
Ookawa.	大川	22 02 39,05	38,75	– 0,30		
Itinomiya.	一ノ宮	48 21 35,70	40,22	+ 4,52	– 0,03	– 0.05
Rokudizô.	六地藏	79 50 31,81	23,88	– 7,93		
Ootani.	大谷	51 47 53,26	56,67	+ 3,41		
Itinomiya.	一ノ宮	97 05 18,73	26,21	+ 7,48	+ 0,26	+ 0,45
Rokudizô.	六地藏	45 56 34,54	29,95	– 4,59		
Nonoduka.	野々塚	36 58 07,70	04,81	– 2,89		
Kuro D.	黒岳	117 50 27,59	30,61	+ 3,02	– 1,94	+ 2,46
Kenasi Y.	毛無山	25 49 16,28	18,31	+ 2,03		
Gosyôtai Y.	御正體山	36 20 17,13	12,08	– 5,05		
Kuro D.	黒岳	80 09 51,79	52,13	+ 0,34	– 1,30	– 1,39
Gosyôtai Y.	御正體山	50 08 12,28	03,86	– 8,42		
Koganezawa.	小金澤山	49 42 56,75	04,82	+ 8,07		
Mean error of a single angle (一角ノ中等誤差) $= m = \sqrt{\frac{[\omega\omega]}{3n}} =$					″ ± 0,826	″ ± 1,172

Table. II— Comparison of lengths of sides, new and old primary triangulation

Base Net			
Sides	邊ノ區別	Differences of lengths new—old	$\frac{\text{Difference}}{\text{side length}}$
		m	
Renkôji M. — Hongô	連光寺村—本郷	+ 0,444	1/42 000
〃 — Tokumaru	〃 —德丸	+ 0,016	1456 000
〃 — Kaminumabe	〃 —上沼部	− 0,195	94 000
〃 — Kano Z.	〃 —鹿野山	+ 0,655	93 000
〃 — Hutago Y.	〃 —二子山	+ 1,869	22 000
〃 — Nagatsuda M.	〃 —長津田村	+ 0,333	40 000
〃 — Sengen Y.	〃 —淺間山	− 0,187	198 000
〃 — Tobinoo Y.	〃 —鳶尾山	− 0,326	58 000
〃 — Tanzawa Y.	〃 —丹澤山	− 0,731	44 000
〃 — Takane	〃 —高根	+ 0,710	27 000
Nagatuda M. — Kaminumabe	長津田村—上沼部	− 0,631	30 000
〃 — Sengen Y.	〃 —淺間山	− 0,494	53 000
〃 — Zama M.	〃 —座間村	− 0,136	37 000
〃 — Tobinoo Y.	〃 —鳶尾山	+ 0,060	241 000
〃 — Simomizo M.	〃 —下溝村	+ 0,146	50 000
〃 — Renkôzi M.	〃 —連光寺村	+ 0,333	40 000
Tobinoo Y. — Renkôzi M.	鳶尾山—連光寺村	− 0,326	58 000
〃 — Simomizo M.	〃 —下溝村	− 0,040	200 000
〃 — Nagatuda M.	〃 —長津田村	+ 0,060	241 000
〃 — Zama M.	〃 —座間村	+ 0,241	42 000
〃 — Sengen Y.	〃 —淺間山	+ 0,400	51 000
Zama M. — Nagatuda M.	座間村—長津田村	− 0,136	37 000
〃 — Tobinoo Y.	〃 —鳶尾山	+ 0,241	42 000
〃 — SimomizoM.	〃 —下溝村	+ 0,240	22 000
Simomizo M. — Nagatuda M.	下溝村—長津田村	+ 0,146	50 000
〃 — Zama M.	〃 —座間村	+ 0,240	22 000
〃 — Tobinoo Y.	〃 —鳶尾山	− 0,040	200 000
Sangen Y. — Tobinoo Y.	淺間山—鳶尾山	+ 0,400	51 000
— Renkôzi M.	〃 —連光寺村	− 0,187	198 000
— Nagatuda M.	〃 —長津田村	− 0,494	53 000
— Kano Z.	〃 —鹿野山	− 1,358	43 000
— Hutago Y.	〃 —二子山	− 0,628	43 000
— Tanzawa Y.	〃 —丹澤山	+ 1,530	14 000

Table II.—— Comparison of lengths of side, new and old primary triangulation——contd.

Principal Points				
Sides		邊ノ區別	Differences of sides	$\frac{\text{Difference}}{\text{side length}}$
			m	
Teruisi Y.	— Tukuba S.	晃石山—筑波山	− 0,428	1/97 000
〃	— Tôkyô	〃 —東京	+ 0,174	452 000
〃	— Dôhira Y.	〃 —堂平山	− 0,392	150 000
Tukuba S.	— Rokudizô	筑波山—六地藏	+ 0,026	3337 000
〃	— Hôten M.	〃 —法典村	− 0,117	484 000
〃	— Tôkyô	〃 —東京	+ 0,090	790 000
〃	— Teruisi Y.	〃 —晃石山	− 0,428	97 000
Dôhira Y.	— Teruisi Y.	堂平山—晃石山	− 0,392	150 000
〃	— Tôkyô	〃 —東京	− 0,046	1370 000
〃	— Takane	〃 —高根	+ 0,062	476 000
〃	— Tanzawa Y.	〃 —丹澤山	+ 0,230	257 000
〃	— Kumotori Y.	〃 —雲取山	− 1,019	27 000
〃	— Kokusi D. Ⅱ	〃 —國師岳Ⅱ	− 1,110	39 000
Kokusi D. Ⅱ	— Dôhira Y.	國師岳Ⅱ—堂平山	− 1,110	39 000
〃	— Kumotori Y.	〃 —雲取山	− 0,086	241 000
〃	— Tanzawa Y.	〃 —丹澤山	+ 0,723	87 000
〃	— Kenasi Y.	〃 —毛無山	− 0,966	61 000
Tôkyô	— Tukuba S.	東京—筑波山	+ 0,090	790 000
〃	— Hoten M.	〃 —法典山	+ 0,061	360 000
〃	— Rokudizô	〃 —六地藏	+ 0,169	285 000
〃	— Kanô Z.	〃 —鹿澤山	+ 1,151	42 000
〃	— Tanzawa Y.	〃 —丹野山	− 1,201	47 000
〃	— Dôhira Y.	〃 —堂平山	− 0,046	1370 000
〃	— Teruisi Y.	〃 —晃石山	+ 0,174	452 000
Tanzawa Y.	— Dôhira .Y	丹澤山—堂平山	+ 0,230	257 000
〃	— Takane	〃 —高根	− 0,193	199 000
〃	— Renkôzi M.	〃 —連光寺村	− 0,731	44 000
〃	— Tôkyô	〃 —東京	− 1,201	47 000
〃	— Kanô Z.	〃 —鹿野山	+ 0,172	442 000
〃	— Bôdai S.	〃 —房大山	+ 0,162	491 000
〃	— Sengen Y.	〃 —淺間山	+ 1,530	14 000
〃	— Manziro D.	〃 —萬城岳	− 2,660	26 000
〃	— Kammuriga T.	〃 —冠ケ岳	− 0,982	30 000
〃	— Asitaka Y.	〃 —愛鷹山	− 1,204	37 000
〃	— Kenasi Y.	〃 —毛無山	− 0,161	355 000
〃	— Gosyotai Y.	〃 —御正體山	− 0,455	46 000
〃	— Koganezawa Y.	〃 —小金澤山	+ 0,391	114 000
〃	— Kokusi D. Ⅱ	〃 —國師岳Ⅱ	+ 0,723	87 000
〃	— Kumotori Y.	〃 —雲取山	+ 0,806	58 000
Rokudizô	— Itinomiya	六地藏—一ノ宮	+ 0,058	309 000
〃	— Nonoduka	〃 —野々塚	+ 0,507	58 000
〃	— Mineoka	〃 —峰岡	+ 0,122	336 000
〃	— Ootani	〃 —大谷	+ 0,164	104 000
〃	— Kanô Z.	〃 —鹿野山	+ 0,252	124 000
〃	— Kuranami	〃 —藏浪	− 0,066	291 000
〃	— Tôkyô	〃 —東京	+ 0,169	285 000
〃	— Hôten M.	〃 —法典村	+ 0,252	150 000
〃	— Tukuba S.	〃 —筑波山	+ 0,026	3337 000

Table II.—— Comparison of lengths of side, new and old primary triangulation——contd.

Principal Points				
Sides		邊ノ區別	Differences of sides	Difference / side length
			m	
Kenasi Y.	— Kokusi D. II	毛無山—國師岳II	− 0,966	1/61 000
〃	— Koganezawa Y.	〃 —小金澤山	− 1,116	38 000
〃	— Kurodake	〃 —黒岳	− 0,481	51 000
〃	— Gosyôtai Y.	〃 —御正體山	+ 0,220	166 000
〃	— Tanzawa y.	〃 —丹澤山	− 0,161	355 009
〃	— Asitaka Y.	〃 —愛鷹山	+ 0,102	336 000
〃	— Manziro D.	〃 —萬城岳	− 1,171	63 000
Kanô Z.	— Hôten M.	鹿野山—法典村	+ 1,097	48 000
〃	— Kuranami	〃 —藏浪	+ 0,638	33 000
〃	— Rokudizô	〃 —六地藏	+ 0,252	124 000
〃	— Ootani	〃 —大谷	− 0,058	272 000
〃	— Mineoka	〃 —峰岡	− 0,923	19 000
〃	— Bôdai S.	〃 —房大山	+ 0,256	141 000
〃	— Nokogiri Y.	〃 —鋸山	+ 0,618	24 000
〃	— Hutago Y.	〃 —二子山	− 0,626	51 000
〃	— Sengen Y.	〃 —淺間山	− 1,358	43 000
〃	— Tanzawa Y.	〃 —丹澤山	+ 0,172	442 000
〃	— Renkôzi M.	〃 —連光寺村	+ 0,655	93 000
〃	— Tôkyô	〃 —東京	+ 1,151	42 000
Bôdai S.	— Nokogiri Y.	房大山—放山	− 0,907	25 000
〃	— Kanô Z.	〃 —鹿野山	+ 0,256	141 000
〃	— Mineoka	〃 —峰岡	+ 0,645	43 000
〃	— Ookawa	〃 —大川	− 0,407	36 000
〃	— Manziro D.	〃 —萬城岳	− 0,403	178 000
〃	— Tanzawa Y.	〃 —丹澤山	+ 0,162	491 000
Manziro D.	— KammurigaT.	萬城岳—冠ヶ岳	− 1,726	24 000
〃	— Tanzawa Y.	〃 —丹澤山	− 2,660	26 000
〃	— Bôdai S.	〃 —房大山	− 0,403	178 000
〃	— Oosima	〃 —大島	− 0,256	146 000
〃	— Kenasi Y.	〃 —毛無山	− 1,171	63 000
〃	— Asitaka Y.	〃 —愛鷹山	− 1,284	32 000

Table II.—— Comparison of lengths of side, new and old primary triangulation——contd.

Supplementary Points			
Sides	邊ノ區別	Differences of sides	Difference / side length
		m	
Kumotori Y. — Dôhira Y.	雲取山—堂平山	− 1,019	1/27 000
〃 — Takane	〃 —高根	− 0,625	62 000
〃 — Tanzawa Y.	〃 —丹澤山	+ 0,806	58 000
〃 —Koganezawa Y.	〃 —小金澤山	+ 0,356	56 000
〃 — Kokusi D. Ⅱ	〃 —國師岳Ⅱ	− 0,086	241 000
Takane — Hongô	高根—本鄉	+ 0,114	127 000
〃 — Renkôzi M.	〃 —連光寺村	+ 0,710	27 000
〃 — Tanzawa Y.	〃 —丹澤山	− 0,193	199 000
〃 — Kumotori Y.	〃 —雲取山	− 0,625	62 000
〃 — Dôhira Y.	〃 —堂平山	+ 0,062	476 000
Tokumaru — Hôten M.	德丸—法典村	− 0,454	63 000
〃 — Kaminumabe	〃 —上沼部	+ 0,402	49 000
〃 — Renkôzi M.	〃 —連光寺村	+ 0,016	1456 000
〃 — Hongô	〃 —本鄉	− 0,140	90 000
Hôten M — Tukuba S.	法典村—筑波山	− 0,117	484 000
〃 — Rokudizô	〃 —六地藏	+ 0,252	150 000
〃 — Kuranami	〃 —藏浪	+ 0,399	79 000
〃 — Kanô Z.	〃 —鹿野山	+ 1,097	48 000
〃 — Kaminumabe	〃 —上沼部	− 0,087	361 000
〃 — Tôkyô	〃 —東京	+ 0,061	360 000
〃 — Tokumaru	〃 —德丸	− 0,454	63 000
Koganezawa Y.— Kumotori Y.	小金澤山—雲取山	+ 0,356	56 000
〃 — Tanzawa Y.	〃 —丹澤山	+ 0,319	114 000
泉 — Gosyôtai Y.	〃 —御正體山	+ 0,038	613 000
〃 — Kuro D.	〃 —黑岳	− 0,598	30 000
〃 — Kenasi Y.	〃 —毛無山	− 1,116	38 000
Kaminumabe — Hôten M.	上沼部—法典村	− 0,087	361 000
〃 — Kuranami	〃 —藏浪	− 0,126	271 000
〃 — Hutago Y.	〃 —二子山	+ 1,387	25 000
〃 — Nagatuda M.	〃 —長津田村	− 0,631	30 000
〃 — Renkôzi M.	〃 —連光寺村	− 0,195	94 000
〃 — Tokumaru	〃 —德丸	+ 0,402	49 000
Gosyôtai Y. — Tanzawa Y.	御正體山—丹澤山	− 0,455	46 000
〃 — Kenasi Y.	〃 —毛無山	+ 0,220	166 000
〃 — Kuro D.	〃 —黑岳	+ 0,618	29 000
〃 —Koganezawa Y.	〃 —小金澤山	+ 0,038	613 000
Kuranami — Rokudizô	藏浪—六地藏	− 0,066	291 000
〃 — Ootani	〃 —大谷	+ 0,121	150 000
〃 — Kanô Z.	〃 —鹿野山	+ 0,638	33 000
〃 — Hutago Y.	〃 —二子山	− 0,156	253 000
〃 — Kaminumabe	〃 —上沼部	− 0,126	271 000
〃 — Hôten M.	〃 —法典村	+ 0,399	79 000
Itinomiya — Nonoduka	一ノ宮—野々塚	+ 0,005	4277 000
〃 — Ootani	〃 —大谷	− 0,377	59 000
〃 — Rokudizô	〃 —六地藏	+ 0,058	309 000

Table II.—— Comparison of lengths of side, new and old primary triangulation——contd.

Supplementary Points			
Sides	邊ノ區別	Differences of sides	Difference / side length
		m	1/
Ootani — Rokudizô	大谷—六地藏	+ 0,164	104 000
〃 — Itinomiya	〃 —一ノ宮	− 0,377	59 000
〃 — Mineoka	〃 --峰岡	− 0,078	310 000
〃 — Kanô Z.	〃 —鹿野山	− 0,058	272 000
〃 — Kuranami	〃 —藏浪	+ 0,121	150 000
Hutago Y. — Kaminumebe	二子山—上沼部	+ 1,387	25 000
〃 — Kuranami	〃 —藏浪	− 0,156	253 000
〃 — Kanô Z.	〃 —鹿野山	− 0,626	51 000
〃 — Nokogiri Y.	〃 —鋸山	− 0,187	135 000
〃 — Sengen Y.	〃 —淺間山	− 0,628	43 000
〃 — Renkôzi	〃 —漣光寺村	+ 1,869	22 000
Kammuriga T. — Tanzawa Y.	冠ケ岳—丹澤山	− 0,982	30 000
〃 — Manziro D.	〃 —萬城岳	− 1,726	24 000
〃 — AsitakaY.	〃 —愛鷹山	− 0,181	109 000
Asitaka Y. — Tanzawa Y.	愛鷹山—丹澤山	− 1,204	37 000
〃 — Kammuriga T.	〃 —冠ケ岳	− 0,181	109 000
〃 — Manziro .D.	〃 —萬城岳	− 1,284	32 000
〃 — Kenasi Y	〃 —毛無山	+ 0,102	336 000
Nonoduka — Itinomiya	野々塚—一ノ宮	+ 0,005	4277 000
〃 — Ookawa	〃 —大川	− 0,761	51 000
〃 — Mineoka	〃 —峰岡	− 0,105	197 000
〃 — Rokudizô	〃 —六地藏	+ 0,507	58 000
Mineoka — Ootani	峰岡—大谷	− 0,078	310,000
〃 — Rokudizô	〃 —六地藏	+ 0,122	336,000
〃 — Nonoduka	〃 —野々塚	− 0,105	197,000
〃 — Ookawa	〃 —大川	− 0,869	24,000
〃 — Bôdai S.	〃 —房大山	+ 0,645	43,000
〃 — Nokogiri Y.	〃 —鋸山	− 1,291	14,000
〃 — Kanô Z.	〃 —鹿野山	− 0,923	19,000
Oosima — Manzirodake	大島—萬城岳	− 0,256	146 000
Ookawa — Mineoka	大川—峰岡	− 0,869	24 000
〃 — Nonoduka	〃 —野々塚	− 0,761	51 000
〃 — Bôdaisan	〃 -房大山	− 0,407	36 000
〃 — Nokogiri Y.	〃 —鋸山	− 3,146	8 000
Nokogiri Y. — Kanô Z.	鋸山—鹿野山	+ 0,618	24 000
〃 — Mineoka	〃 —峰岡	− 1,291	14 000
〃 — Ookawa	〃 —大川	− 3,146	8 000
〃 — Bôdaisan	〃 —房大山	− 0,907	25 000
〃 — Hutago Y.	〃 —二子山	− 0,187	135 000
Kurodake — Koganezawa Y.	黑岳—小金澤山	− 0,598	30 000
〃 — Gosyôtai Y.	〃 —御正體山	+ 0,618	29 000
〃 — Kenasi Y.	〃 —毛無山	− 0,481	51 000
Hongô — Tokumaru	本鄉—德丸	− 0,140	90 000
〃 — Renkôzi M.	〃 —連光寺村	+ 0,444	42 000
〃 — Takane	〃 —高根	+ 0,114	127 000

Table III.— Comparison of new and old geographic positions of primary triangulation points

I. (Teruisiyama and its azimuth to Tukubasan fixed)									
Point	名 稱	new Latitudes old Latitudes	difference in second New − Old	difference in length $\Delta\varphi$	New Longitudes Old Longitudes	difference in second New − Old	difference in length Δl	Displacement	
								$\sqrt{\Delta\varphi^2 + \Delta l^2}$	Direction from old position, clockwise from north
		° ′ ″	″	m	° ′ ″	″	m	m	°
Teruisi Y.	晃石山	36 21 25,6254 25,6254	0,0000	0,000	139 40 43,0456 43,0456	0,0000	0,000	0,000	
Tukuba S.	筑波山	36 13 19,9614 19,9563	+ 0,0051	+ 0,157	140 06 35,9232 35,9391	− 0,0159	− 0,397	0,427	292
Dôhira Y.	堂平山	36 00 09,2578 09,2516	+ 0,0062	+ 0,191	139 11 35,7505 35,7360	+ 0,0145	+ 0,363	0,410	62
Tôkyô	東京	35 39 17,5094 17,5148	+ 0,0054	− 0,166	139 44 40,5031 40,5020	+ 0,0011	+ 0,028	0,168	170
Rokudizô	六地藏	35 26 39,7351 39,7279	+ 0,0072	+ 0,222	140 12 30,6122 30,5948	+ 0,0174	+ 0,439	0,492	63
Kanô Z.	鹿野山	35 15 06,0759 06,1058	− 0,0299	− 0,921	139 57 32,3178 32,2712	+ 0,0466	+ 1,178	1,495	128
Bôdai S.	房大山	— —	− 0,0305	− 0,940	— —	+ 0,0254	+ 0,644	1,139	146
Tanzawa Y.	丹澤山	35 28 15,7924 15,7949	− 0,0025	− 0,077	139 09 57,0976 57,0468	+ 0,0508	+ 1,281	1,283	93
Kokusi D. II	國師岳II	35 54 52,0110 51,9819	+ 0,0291	+ 0,897	138 43 51,5634 51,5103	+ 0,0531	+ 1,331	1,605	56
Kenasi Y.	毛無山	35 24 38,6525 38,5894	+ 0,0631	+ 1,944	138 32 29,0459 28,9982	+ 0,0477	+ 1,203	2,286	32

Table III.—— Comparison of new and old geographic positions of primary triangulation points——contd.

I. (Teruisiyama and its azimuth to Tukubasan fixed)

Point	名稱	new Latitudes old Latitudes	difference in second New−Old	difference in length Δφ	New Longitudes Old Longitudes	difference in second New−Old	difference in length Δl	Displacement	
								$\sqrt{\Delta\varphi^2 + \Delta l^2}$	Direction from old position, clockwise from nroth
		° ′ ″	″	m	° ′ ″	″	m	m	°
Manziro D.	萬城岳	——	+ 0,0917	+ 2,826	——	+ 0,0176	+ 0,447	2,861	9
Simomizo M.	下溝村	35 31 40,8654 40,8847	− 0,0193	− 0,595	139 24 34,6642 34,6159	+ 0,0483	+ 1,217	1,355	116
Zama M.	座間村	35 29 12,9806 13,0046	− 0,0240	− 0,740	139 26 14,8912 14,8331	+ 0,0581	+ 1,464	1,640	117
Nagatuda M.	長津田村	35 30 30,6090 30,6334	− 0,0244	− 0,752	139 29 12,4556 12,4032	+ 0,0524	+ 1,320	1,519	120
Tobinô Y.	鳶尾山	35 30 04,4556 04,4740	− 0,0184	− 0,567	139 19 40,4982 40,4486	+ 0,0496	+ 1,250	1,373	114
Renkôzi M.	連光寺圓	35 37 39,0758 39,0920	− 0,0162	− 0,499	139 28 05,7712 05,7444	+ 0,0268	+ 0,674	0,839	127
Sengen Y.	淺間山	35 19 07,8966 07,9302	− 0,0336	− 1,035	139 18 55,9256 55,8247	+ 0,1009	+ 2,548	2,750	112
Kamuriga D.	冠ヶ岳	35 13 48,5098 48,4752	+ 0,0346	+ 1,066	139 01 26,5199 26,4746	+ 0,0453	+ 1,145	1,564	47
Asitaka Y.	愛鷹山	35 11 42,8593 42,8018	+ 0,0575	+ 1,772	138 48 39,1255 39,0786	+ 0,0469	+ 1,186	2,132	34
Mishôtai Y.	御正體山	35 29 01,2948 01,2792	+ 0,0156	+ 0,481	138 56 05,1601 05,0898	+ 0,0703	+ 1,772	1,836	75
Koganezawa Y.	小金澤山	35 41 07,1175 07,1056	+ 0,0119	+ 0,367	138 51 46,6306 46,5814	+ 0.0492	+ 1,237	1,290	73
Kumotori Y.	雲取山	35 51 08,3524 08,3272	+ 0,0252	+ 0,777	138 56 49,5082 49,4604	+ 0,0478	+ 1,199	1,429	57

Table III.—— Comparison of new and old geographic positions of primary triangulation points——contd.

I. (Teruisiyama and its azimuth to Tukubasan fixed)

Point	名　称	new Latitudes old Latitudes	difference in second New−Old	difference in length $\Delta\varphi$	New Longitudes Old Longitudes	difference in second New−Old	difference in length Δl	Displacement	
								$\sqrt{\Delta\varphi^2 + \Delta l^2}$	Direction from old position, clockwise from noath
		° ′ ″	″	m	° ′ ″	″	m	m	°
Takane	高　根	35 46 34,6149 34,6095	+ 0,0054	+ 0,166	139 21 55,5600 55,5435	+ 0,0165	+ 0,414	0,446	68
Hongô	本　郷	35 47 23,6120 23,6120	0,0000	0,000	139 31 27,6548 27,6330	+ 0,0218	+ 0,547	0,547	90
Tokumaru	徳　丸	35 46 01,4906 01,4952	− 0,0046	− 0,142	139 39 38,1574 38,1428	+ 0,0146	+ 0,367	0,394	111
Hutago Y.	二子山	—— ——	− 0,0692	− 2,132	—— ——	+ 0,0677	+ 1,711	2,734	141
Kaminumabe	上沼部	35 35 23,7744 23,7922	− 0,0178	− 0,549	139 39 58,9150 58,8969	+ 0,0181	+ 0,456	0,714	140
Hôten M.	法典村	35 43 25,4528 25,4465	+ 0,0063	+ 0,194	139 58 19,3073 19,3088	− 0,0015	− 0,038	0,198	349
Kuranami	藏　浪	35 26 28,2250 28,2305	− 0,0055	− 0,169	139 59 47,9542 47,9336	+ 0,0206	+ 0,520	0,547	108
Ootani	大　谷	35 18 37,9891 37,9936	− 0,0045	− 0,139	140 07 00,8335 00,8036	+ 0,0299	+ 0,755	0,768	100
Nonoduka	野々塚	35 10 44,4758 44,4846	− 0,0088	− 0,271	140 14 04,1201 04,0894	+ 0,0307	+ 0,777	0,823	109
Nokogiri Y.	鋸　山	—— ——	− 0,0682	− 2,102	—— ——	+ 0,0588	+ 1,488	2,570	145
Mineoka	峰　岡	35 06 22,0156 22,0180	− 0,0024	− 0,074	140 01 33,5518 33,5196	+ 0,0322	+ 0,815	0,818	95
Ookawa	大　川	—— ——	+ 0,0303	+ 0,934	—— ——	+ 0,0256	+ 0,650	1,200	34

Table III.—— Comparison of new and old geographic positions of primary triangulation points——contd.

I. (Teruisiyama and its azimuth to Tukubasan fixed)

Point	名　稱	new Latitudes old Latitudes	difference in second New − Old	difference in leagth $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New − Old	Differenece in leagth Δl	Displacement	
								$\sqrt{\Delta\varphi^2 + \Delta l^2}$	Direction from old position, clockwsie from north
		° ′ ″	″	m	° ′ ″	″	m	m	°
Itinomiya	一ノ宮	35 20 30,2792 30,2784	+ 0,0008	+ 0,025	140 21 37,8096 37,7960	+ 0,0136	+ 0,343	0,344	86
Oosima	大島	═══	+ 0,1216	+ 3,717	═══	+ 0,0210	+ 0.534	3,784	8
Kurodake	黑岳	35 32 55,8671 55,8338	+ 0,0333	+ 1,026	138 45 09,2970 09,2442	+ 0,0528	+ 1,331	1,681	52

備考，新舊經緯度ノ欄中 ═══ 部ハ秘密地圖ノ爲削除セルモノナリ

Remark : —— Blanks in the columns of latitudes and longitudes are due to the points being situated within the prohibited area.

Table III.—— Comparison of new and old geographic positions of primary triangulation points——contd.

II. (Kokusidake and its azimuth to Kenasiyama fixed)

Point	名　稱	new Latitudes old Latitudes	difference in second New – Old	difference in leagth $\Delta\varphi$	New Longitudes Old Longitudes	difference in second New - Old	difference in length Δl	Displacement	
								$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north
		° ′ ″	″	m	° ′ ″	″	m	m	°
Kokusidake Ⅱ	國師岳Ⅱ	35 54 51,9819 51,9819	0,0000	0,0000	138 43 51,5103 51,5103	0,0000	0,000	0,000	
Teruisi Y.	晃石山	36 21 25,6269 25,6254	+ 0,0015	+ 0,046	139 40 42,9706 43,0456	– 0,0750	– 1,870	1,871	271
Tukubasan	筑波山	36 13 19,9764 19,9563	+ 0,0201	+ 0,619	140 06 35,8550 35,9391	– 0,0841	– 2,102	2,191	286
Dôhira Y.	堂平山	36 00 09,2434 09,2516	– 0,0082	– 0,253	139 11 35,6931 35,7360	– 0,0429	– 1,074	1,103	257
Tôkyô	東　京	35 39 17,5126 17,5148	– 0,0022	– 0,068	139 44 40,4621 40,5020	– 0,0399	– 1,003	1,005	266
Rokudizô	六地藏	35 26 39,7530 39,7279	+ 0,0251	+ 0,773	140 12 30,5809 30,5948	– 0.0139	– 0,350	0,849	336
Kanô Z.	鹿野山	35 15 06,0858 06,1058	– 0,0200	– 0,616	139 57 32,2958 32,2712	+ 0,0246	+ 0,621	0,875	135
Bôdaisan	房大山	— —	– 0,0263	– 0,810	— —	+ 0,0175	+ 0,444	0,924	151
Tanzawa Y.	丹澤山	35 28 15,7774 15,7949	– 0,0175	– 0,539	139 09 57,0660 57,0468	+ 0,0192	+ 0,484	0,724	138
Kenasi Y.	毛無山	35 24 38,6176 38,5894	+ 0,0282	+ 0,869	138 32 29,0174 28,9982	+ 0,0192	+ 0,485	0,995	29
Manzirodake	萬城岳	— —	+ 0,0709	+ 2,185	— —	+ 0,0149	+ 0,379	2,218	10
Simomizo M.	下溝村	35 31 40,8580 40,8847	– 0,0267	– 0,823	139 24 34,6296 34,6159	+ 0,0137	+ 0,345	0,892	157

Table III.—— Comparison of new and old geographic positions of primary triangulation points ——contd.

II. (Kokusidake and its azimuth to Kenasiyama fixed)

Point	名 稱	new Latitudes old Latitudes	difference in second New−Old	difference in length Δφ	New Longitudes Old Longitndes	difference in second New−Old	difference in length Δl	Displacement	
								$\sqrt{\Delta\varphi^2 + \Delta l^2}$	direction from old position, clockwise from north
		° ′ ″	″	m	° ′ ″	″	m	m	°
Zama M.	座間村	35 29 12,9741 13,0046	− 0,0305	− 0,940	139 26 14,8586 14,8331	+ 0,0255	+ 0,643	1,139	146
Nagatuda M.	長津田村	35 30 30,6040 30,6334	− 0,0294	− 0,906	139 29 12,4219 12,4032	+ 0,0187	+ 0,471	1,021	153
Tobinoo Y.	鳶尾山	35 30 04,4456 04,4740	− 0,0284	− 0,875	139 19 40,4649 40,4486	+ 0,0163	+ 0,411	0,967	155
Renkôzi M.	連光寺村	35 37 39,0704 39,0920	− 0,0216	− 0,666	139 28 05,7322 05,7444	− 0,0122	− 0,307	0,733	205
Sengen Y.	淺間山	35 19 07,8862 07,9302	− 0,0440	− 1,356	139 18 55,9007 55,8247	+ 0,0760	+ 1,919	2,350	125
Kamuriga T.	冠ヶ岳	35 13 48,4900 48,4752	+ 0,0148	+ 0,456	139 01 26,4997 26,4746	+ 0,0251	+ 0,635	0,782	54
Asitaka Y.	愛鷹山	35 11 42,8330 42,8018	+ 0,0312	+ 0,961	138 48 39,1072 39,0786	+ 0,0286	+ 0,724	1,203	37
Misyôtai Y.	御正體山	35 29 01,2724 01,2792	− 0,0068	− 0,210	138 56 05,1280 05,0898	+ 0,0382	+ 0,963	0,986	102
Koganezawa Y.	小金澤山	35 41 07,0928 07,1056	− 0,0128	− 0,394	138 51 46,5888 46,5814	+ 0,0074	+ 0,186	0,436	155
Kumotori Y.	雲取山	35 51 08,3302 08,3272	+ 0,0030	+ 0,092	138 56 49,4580 49,4604	− 0,0024	+ 0,060	0,110	327
Takane	高根	35 46 34,6062 34,6095	− 0,0033	− 0,102	139 21 55,5140 55,5435	− 0,0295	− 0,740	0,747	262
Hongô	本鄉	35 47 23,6083 23,6120	− 0,0037	− 0,114	139 31 27,6080 27,6330	− 0,0250	− 0,627	0,637	260

Table III.—— Comparison of new and old geographic positions of primary triangulation points——contd.

II. (Kokusidake and its azimuth to Kenasiyama fixed)

Point	名　稱	new Latitudes old Latitudes	difference in second New－Old	difference in length Δφ	New Longitudes Old Longitudes	difference in second New－Old	difference in length Δl	Displacement $\sqrt{\Delta\varphi^2 + \Delta l^2}$	Displacement Direction from old position, clockwise from north
		° ′ ″	″	m	° ′ ″	″	m	m	°
Tokumaru	徳　丸	35 46 01,4912 01,4952	− 0,0040	− 0,123	139 39 38,1115 38,1428	− 0,0313	− 0,785	0,795	261
Hutago Y.	二子山	—— ——	− 0,0703	− 2,166	—— ——	+ 0,0446	+ 1,126	2,441	153
Kaminumabe	上沼部	35 35 23,7752 23,7922	− 0,0170	− 0,524	139 39 58,8768 58,8969	− 0,0201	− 0,565	0,728	224
Hoten M.	法典村	35 43 25,4632 25,4465	+ 0,0167	+ 0,515	139 58 19,2630 19,3088	− 0,0458	− 1,152	1,262	294
Kuranami	藏　浪	35 26 28,2361 28,2305	+ 0,0056	+ 0,173	139 59 47,9230 47,9336	− 0,0106	− 0,267	0,318	303
Ootani	大　谷	35 18 38,0040 37,9936	+ 0,0104	+ 0,320	140 07 00,8086 00,8036	+ 0,0050	+ 0,126	0,344	22
Nonoduka	野々塚	35 10 44,4950 44,4848	+ 0,0102	+ 0,314	140 14 04,1022 04,0894	+ 0,0128	+ 0,324	0,451	46
Nokogiri Y.	鋸　山	—— ——	− 0,0620	− 1,910	—— ——	+ 0,0414	+ 1,048	2,179	151
Mineoka	峰　岡	35 06 22,0276 22,0180	+ 0,0096	+ 0,296	140 1 33,5370 33,5196	+ 0,0174	+ 0,440	0,530	56
Ookawa	大　川	—— ——	+ 0,0395	+ 1,217	—— ——	+ 0,0190	+ 0,482	1,309	22
Itinomiya	一ノ宮	35 20 30,3018 30,2784	+ 0,0234	+ 0,721	140 21 37,7836 37,7962	− 0,0126	− 0,318	0,788	336
Oosima	大　島	—— ——	+ 0,1132	+ 3,488	—— ——	+ 0,0238	+ 0,599	3,539	10

Table III.—— Comparison of new and old geographic positions of primary triangulation points——contd.

II. (Kokusidake and its azimuth to Kenasiyama fixed)

Point	名稱	new Latitudes old Latitudes	difference in second old – new	difference in length $\Delta\varphi$	New Longitudes Old Longitudes	difference in second Old – New	difference in length Δl	Dispacement	
								$\sqrt{\Delta\varphi^2 + \Delta l^2}$	Direction from old position, clockwise from north
		° ′ ″	″	m	° ′ ″	″	m	m	°
Kuro D.	黑岳	35 32 55,8388 55,8338	+ 0,0050	+ 0,154	138 45 09,2618 09,2442	+ 0,0176	+ 0,444	0,470	71

備考，新舊經緯度ノ欄中 ＿＿ 部ハ秘密地圖ノ爲削除セルモノナリ

Remark : — Blanks in the columns of latitudes and longitudes ard due to the points being situated within the prohibited area.

Table IV.— Comparison of new and old geogaraphic positions of secondary triangulation points.

Point	名　稱	New Latitudes Old Latitudes	Differance in second New – Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New – Old	Difference in leagth Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement: Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kawabata	川　端	35 43 57,4714 57,4933	– 0,0219	– 0,675	139 51 1,2104 1,2111	– 0,0007	– 0,018	0,675	182	
Otiai	落　合	35 42 54,3340 54,3578	– 0,0238	– 0,734	139 42 5,4263 5,4346	– 0,0083	– 0,209	0,762	196	
Ninohasi	二ノ橋	35 40 19,2227 19,2408	– 0,0181	– 0,558	139 47 21,5784 21,5812	– 0,0028	– 0,070	0,562	187	
Sendagaya	千駄ケ谷	35 40 12,3221 12,3502	– 0,0281	– 0,866	139 43 5,4494 5,4582	– 0,0088	– 0,221	0,894	194	
Sinagawa	品　川	35 37 16,3687 16,4009	– 0,0322	– 0,992	139 44 16,8748 16,8814	– 0,0066	– 0,166	1,006	190	
Daita	代　田	35 39 10,3754 10,4072	– 0,0318	– 0,980	139 39 51,6942 51,6959	– 0,0017	– 0,043	0,981	183	
Hanamata	花　又	35 47 23,1498 23,1528	– 0,0031	– 0,095	139 49 41,8084 41,8215	– 0,0131	– 0,329	0,342	254	
Nakano	中　野	35 42 14,8307 14,8520	– 0,0213	– 0,656	139 39 45,7172 45,7198	– 0,0026	– 0,065	0,659	186	
Kônodai	國府臺	35 44 41,5988 41,6209	– 0,0221	– 0,681	139 54 4,6579 4,6586	– 0,0007	– 0,018	0,681	182	
Higasikaizuka	東貝塚	39 49 56,5482 56,5539	– 0,0057	– 0,176	139 46 0,3385 0,3300	+ 0,0085	+ 0,213	0,276	130	

Table IV.—— Comparison of new and old geographic positions of secondary triangulation points——contd.

Point	名稱	Now Latitudes Old Latitudes	Difference in second New − Old	Difference in length $\Delta\varphi$	Naw Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2 + \Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Hanadate	花立	— —	− 0,0784	− 2,694	— —	+ 0,0461	+ 1,163	2,934	157	三浦半島
Oogusu Y.	大楠山	— —	− 0,0968	− 2,983	— —	+ 0,0592	+ 1,496	3,337	153	〃
Sengen Y.	淺間山	— —	− 0,0971	− 2,992	— —	+ 0,0494	+ 1,249	3,242	157	〃
Nagai M.	長井村	— —	− 0,1076	− 3,316	— —	+ 0,0420	+ 1,062	3,482	162	〃
Hitomi	人見	35 40 40,5496 40,5772	− 0,0276	− 0,851	139 30 20,0727 20,0692	+ 0,0035	+ 0,088	0,856	174	
Mure	牟禮	35 41 12,1674 12,1947	− 0,0273	− 0,841	139 35 10,6595 10,6646	− 0,0051	− 0,128	0,851	189	
Kamisueyosi	上末吉	35 31 15,2822 15,3224	− 0,0402	− 1,239	139 43 11,5926 11.5760	+ 0,0166	+ 0,418	1,308	161	
Katayama	片山	35 46 39,2138 39,2372	− 0,0234	− 0,721	139 35 12,7564 12,7708	− 0,0144	− 0,362	0,807	207	
Haneda	羽田	35 32 35,8846 35,9159	− 0,0313	− 0,965	139 45 34,9370 34,9412	− 0,0042	− 0,106	0,971	186	
Kitami	喜多見	35 37 46,3766 46,4145	− 0,0379	− 1,168	139 36 18,6692 18,6681	+ 0,0011	+ 0,028	1,168	179	
Tutihasi	土橋	35 34 49,3755 49,4217	− 0,0462	− 1,423	139 34 17,9320 17,9243	+ 0,0077	+ 0,194	1,436	172	
Koyasu M.	子安村	35 29 23,2622 23,3050	− 0,0428	− 1,319	139 39 46,5464 46,5212	+ 0,0252	+ 0,635	1,463	154	
Hosoyama	細山	35 37 3,2394 3,2823	− 0,0429	− 1,322	139 31 21,9292 21,9278	+ 0,0014	+ 0,035	1,322	179	

Table IV.—— Comparison of new and old geographic positions of secondary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New - Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement		備考
								$\sqrt{\Delta\varphi^2 + \Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	*m*	° ′ ″	″	*m*	*m*	°	
Kamisugata	上菅田	35 29 33,5428 33,5916	− 0,0488	− 1,504	139 33 29,7228 29,6978	+ 0,0250	+ 0,630	1,631	157	
Nagata M.	永田村	35 25 31,1670 31,2220	− 0,0550	− 1,694	139 35 21.8847 21,8429	+ 0,0418	+ 1,055	1,996	148	
Enkaizan	圓海山	— —	− 0,0748	− 2,305	— —	+ 0,0556	+ 1,404	2,699	149	三浦半島
Miyamoto	宮本	— —	− 0,0510	− 1.572	— —	+ 0,0186	+ 0,471	1,641	163	房總地方
Tenman	天面	35 4 32,3161 32,3322	− 0,0161	− 0,496	140 4 28,5113 28,4875	+ 0,0238	+ 0,603	0,781	129	
Miyasita	宮下	— —	− 0,0400	− 1,233	— —	+ 0,0164	+ 0,416	1,301	161	房總地方
Takehara	竹原	— —	− 0,0218	− 0,672	— —	+ 0,0104	+ 0,264	0,722	159	〃
Sunomiya	洲宮	— —	− 0,0533	− 1,642	— —	+ 0,0156	+ 0,396	1,689	166	〃
Mera	布良	— —	− 0,0526	− 1,621	— —	+ 0,0150	+ 0,381	1,665	167	〃
Ryôsima	瀧島	— —	− 0,0784	− 2,416	— —	+ 0,0278	+ 0,704	2,528	164	〃
Iyodake	伊豫岳	— —	− 0,0557	− 1,716	— —	+ 0,0272	+ 0,689	1,849	158	〃
Ogawa	小川	35 3 11,0046 11,0218	− 0,0172	− 0,530	140 0 22,1054 22,0870	+ 0,0184	+ 0,466	0,706	140	
Nasizawa	梨澤	— —	− 0,0596	− 1,836	— —	+ 0,0377	+ 0,954	2,069	153	房總地方

Table IV.—— Comparison of new and old geographic positions of secondary triangulation points——contd

Point	名稱	New Latitudes Old Latitudes	Difference in second New−Old	Difference in length Δφ	New Longitudes Old Latitudes	Difference in second New - Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement: Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kiwada	黃和田	35 12 40,9955 41,0125	− 0,0170	− 0,524	140 8 56,2522 56,2170	+ 0,0352	+ 0,890	1,032	120	
Izumi	和泉	35 8 11,7766 11,7973	− 0,0207	− 0,638	140 7 12,0258 11,9810	+ 0,0448	+ 1,134	1,301	119	
Narikawa	成川	35 9 15,1418 15,1684	− 0,0266	− 0,820	140 1 24,4912 24,4503	+ 0,0409	+ 1,035	1.320	128	
Ootomi	大戸見	35 13 8,9269 8,9494	− 0,0225	− 0,693	140 2 50,4367 50,3982	+ 0,0385	+ 0,974	1.195	125	
Sasage	筵毛	— —	− 0,0597	− 1,839	— —	+ 0,0428	+ 1,082	2,134	150	房總地方
Yamatakino	山瀑野	35 16 59,0514 59,0684	− 0,0170	− 0,524	140 1 52,6784 52.6467	+ 0,0317	+ 0,801	0,957	123	
Huttu	富津	— —	− 0,0598	− 1,842	— —	+ 0,0460	+ 1,162	2,178	148	房總地方
Hitomi	人見	35 20 3,2355 3,2793	− 0,0438	− 1,350	139 52 24,5656 24,5337	+ 0,0319	+ 0,805	1,572	149	
Yana	矢那	35 19 55,5803 55,6040	− 0,0237	− 0,730	139 58 39,7201 39,6930	+ 0,0271	+ 0,684	1,000	137	
Kurito	畔戸	35 25 9,2483 9,2732	− 0,0249	− 0,767	139 54 12,8644 12,8444	+ 0,0200	+ 0,505	0,918	147	
Sôri	相里	35 22 51,9531 51,9774	− 0,0243	− 0,749	139 57 1,0557 1,0333	+ 0,0224	+ 0,591	0,954	142	
Tanaka	田中	35 41 31,6486 31,6870	− 0,0384	− 1,171	139 20 30,6714 30,6729	− 0,0015	− 0,038	1,172	182	
Yosinoeki	吉野驛	35 37 35,2952 35,3394	− 0,0442	− 1,362	139 9 47,0670 47,0399	+ 0,0271	+ 0,682	1,523	153	

Table IV.—— Comparison of new and old geographic positions of secondary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New - Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement		備　考
								$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Dôryô	道　了	35 37 19,0255 19,0682	− 0,0427	− 1,316	139 21 6,5015 6,4938	+ 0,0077	+ 0,194	1,330	172	
Dôdokoro Y.	堂 所 山	35 34 27,5582 27,6119	− 0,0537	− 1,655	139 15 13,0216 13,0037	+ 0,0179	+ 0,451	1,715	165	
Simokuzawa M.	下九澤村	35 34 17,4220 17,4710	− 0,0490	− 1,510	139 21 22,5838 22,5664	+ 0,0174	+ 0,438	1,572	164	
Yake Y.	燒　山	35 32 8,2092 8,2588	− 0,0496	− 1,529	139 10 0,7946 0,7580	+ 0,0366	+ 0,822	1,736	152	
Oomure Y.	大 群 山	35 30 27,7744 27,8158	− 0,0414	− 1,276	139 4 18,2812 18,2378	+ 0,0434	+ 1,094	1,681	139	
Nisiyama M.	西 山 村	35 30 13,9019 13,9599	− 0,0580	− 1,788	139 16 42,2790 42,2474	+ 0,0316	+ 0,796	1,957	156	
Yotukumura	世 附 村	35 25 38.3888 38,4282	− 0,0394	− 1,214	139 1 42,2982 42,2510	+ 0,0472	+ 1,192	1,513	136	
Yosioka M.	吉 岡 村	35 25 29,4584 29,5200	− 0,0616	− 1,899	139 24 46,5090 46,4538	+ 0,0552	+ 1,391	2,355	144	
Sannomiya M.	三ノ宮村	35 23 57,0392 57,0872	− 0,0480	− 1,479	139 15 27,2390 27,1958	+ 0,0432	+ 1,090	1,837	144	
Numame M.	沼 目 村	35 23 27,1332 27,1882	− 0,0550	− 1,695	139 19 59,5752 59,5064	+ 0,0688	+ 1,736	2,426	134	
Minasegawa M.	皆瀬川村	35 23 10,8294 10,8668	− 0,0374	− 1,153	139 6 20,4046 20,3520	+ 0,0526	+ 1,328	1,758	131	
AmanumaM.	甘 沼 村	35 21 6,1535 6,2230	− 0,0695	− 2,142	139 25 7,0687 6,9908	+ 0,0779	+ 1,967	2,908	137	
Takaotiba	鷹 落 場	35 20 11,9179 11,9578	− 0,0399	− 1,230	139 2 22,7790 22,7194	+ 0,0596	+ 1,505	1,944	129	

Table IV.—— Comparison of new and old geographic positions of secondary triangulation points——contd.

Point	名　稱	New Latitudes	Difference in leagth	Differende in length	New Latituds Old	Difference in second	Difference in length	Displacement		備　考
		Old Latitudes	New - Old	Δφ	Old Latitudes	New−Old	Δl	$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Sohi M.	曾比村	35 18 32,9048 32,9515	− 0,0467	− 1,439	139 8 29,1178 29,0984	+ 0,0194	+ 0,490	1,520	161	
Nyôdô D.	入道岳	35 17 52,7495 52,7796	− 0,0301	− 0,928	136 2 42,6520 42,5642	+ 0,0878	+ 2,218	2,404	113	
Sogayama	曾我山	35 17 51,7034 51,7598	− 0,0564	− 1,738	139 12 33,0487 33,0068	+ 0,0419	+ 1,058	2,034	149	
Enosima	江ノ島	35 17 47,7756 47,8604	− 0,0848	− 2,614	139 28 54,7060 54,6389	+ 0,0671	+ 1,692	3,114	147	
Kamiyama M.	神山村	35 13 52,6278 52,6316	− 0,0038	− 0,117	138 56 7,2176 7,2017	+ 0,0159	+ 0,402	0,419	107	
Isibasimura	石橋村	35 12 25,9306 25,9776	− 0,0470	− 1,448	139 6 35,4474 35,4268	+ 0,0206	+ 0,521	1,539	160	
Sanomura	佐野村	35 9 17,3738 17,3577	+ 0,0161	+ 0,496	138 55 33,3217 33,2143	+ 0,1074	+ 2,718	2,763	80	
Miyaue M.	宮上村	35 9 3,9431 3,9524	− 0,0093	− 0,287	139 1 55,0922 55,0708	+ 0,0214	+ 0,542	0,613	118	
Manadurumisaki	眞鶴岬	35 8 37,7908 37,8255	− 0,0347	− 1,069	139 8 58,8966 58,8778	+ 0,0188	+ 0,476	1,170	156	
Daiba M.	大場村	35 6 21,4536 21,4614	− 0,0078	− 0,240	138 57 8,0377 8,0290	+ 0,0087	+ 0,220	0,326	137	
Kurodake	玄　岳	35 4 42,1028 42,1114	− 0,0086	− 0,265	139 1 52,5288 52,5151	+ 0,0137	+ 0,347	0,437	127	
Hatusima	初　島	35 2 17,6769 17,7302	− 0,0533	− 1,643	139 10 15,4554 15,4788	− 0,0236	− 0,593	1,746	200	
Tanagasira Y.	棚頭山	35 39 52,7390 52,7661	− 0,0274	− 0,844	139 1 28,5528 28,5292	+ 0,0236	+ 0,604	1,038	144	

Table IV.—— Comparison of new and old geographic positions of secondary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New - Old	Difference in length $\Delta\varphi$	New Latitudes Old Latitudes	Difference tn sedond New – Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Tokukura Y.	德倉山	35 4 30,6391 30,6464	− 0,0073	− 0,225	138 53 29,6409 29,6418	− 0,0009	− 0,023	0,226	186	
Kosaka M.	小坂村	35 0 30,5916 30,5996	− 0,0080	− 0,247	138 55 24,4183 24,4192	− 0,0009	− 0,023	0,247	185	
Enasi M.	江梨村	35 0 6,5904 6,5964	− 0,0060	− 0,185	138 48 2,7059 2,7072	− 0,0013	− 0,033	0,188	190	
Sukumo Y.	巢雲山	35 0 6,4317 6,4473	− 0,0156	− 0,481	139 2 25,6916 25,6921	− 0,0005	− 0,013	0,481	182	
Ryôgababa	龍ヶ馬場	35 22 11,4100 11,4330	− 0,0230	− 0,709	138 49 29,0834 29,0434	+ 0,0400	+ 1,009	1,233	125	
Inno M.	印野村	35 17 47,8644 47,8719	− 0,0075	− 0,231	138 49 40,9357 40,9066	+ 0,0291	+ 0,735	0,770	107	
Zyûriki	十里木	35 17 7,4112 7,4089	+ 0,0023	+ 0,071	138 47 8,7710 8,7413	+ 0,0297	+ 0,751	0,754	85	
Simowada	下和田村	35 14 4,3992 4,4079	− 0,0087	− 0,268	138 51 8,9400 8,9325	+ 0,0075	+ 0,190	0,328	145	
Oodake	大　岳	35 45 43,2178 43,2538	− 0,0360	− 1,110	139 8 0,9444 0,9288	+ 0,0156	+ 0,392	1,177	161	
Tokura M.	戶倉村	35 41 52,0084 52,0447	− 0,0363	− 1,119	139 12 0,0896 0,0820	+ 0,0076	+ 0,191	1,135	170	
Nisihara M.	西原村	35 41 44,5143 44,5420	− 0,0277	− 0,854	139 4 2,8823 2,8582	+ 0,0241	+ 0,606	1,047	145	
Sanokawa M.	佐ノ川村	35 40 9,0434 9,0764	− 0,0330	− 1,017	139 8 8,0544 8,0319	+ 0,0225	+ 0,566	1,164	151	
Kuradake Y.	鞍岳山	35 34 50,7482 50,7800	− 0,0318	− 0,980	139 1 22,7818 22,7422	+ 0,0396	+ 0,996	1,397	135	

aTble IV.—— Comparison of new and old geographic positions of secondary triangulation points——contd.

Point	名稱	New Latitudes / Old Latitudes	Difference in second New – Old	Difference in length Δφ	New Latitudes / Old Latitudes	Difference in second New – Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2 + \Delta l^2}$	Displacement: Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Sanotôge	佐野峠	35 43 4,5848 4,6072	– 0,0224	– 0,690	138 53 10,0975 10,0834	+ 0,0141	+ 0,354	0,776	153	
Yôzawa Y.	川澤山	35 39 43,5904 43,6151	– 0,0247	– 0,761	138 56 12,3783 12,3634	+ 0,0149	+ 0,375	0,848	154	
Takiko Y.	瀧子山	35 37 36,6424 36,6602	– 0,0178	– 0,549	138 51 20,4070 20,3906	+ 0,0164	+ 0,414	0,688	143	
Osozawa Y.	遲澤山	35 34 24,1468 24,1752	– 0,0284	– 0,875	138 57 15,2532 15,2215	+ 0,0317	+ 0,798	1,184	138	
Mizutôge	水峠	35 32 45,7398 45,7601	– 0,0203	– 0,626	138 48 44,4306 44,3926	+ 0,0380	+ 0,957	1,144	123	
Danno Y.	檀ノ山	35 29 27,2570 27,2660	– 0,0090	– 0,277	138 42 38,6088 38,5932	+ 0,0156	+ 0,393	0,481	125	
Ogura Y.	小倉山	35 27 26,0288 26,0439	– 0,0151	– 0,465	138 48 3,7414 3,7043	+ 0,0371	+ 0,936	1,045	116	
Oohira Y.	大平山	35 26 8,6080 8,6280	– 0,0200	– 0,616	138 52 56,9286 56,8875	+ 0,0411	+ 1,037	1,206	111	
Oodake	王岳	35 30 35,9300 35,9336	– 0,0036	– 0,111	138 38 52,5556 52,5576	– 0,0020	– 0,050	0,122	235	
Itikawa daimon M.	市川大門村	35 31 45,3834 45,3834	– 0,0000	– 0,000	138 31 37,3968 37,4056	– 0,0088	– 0,222	0,222	270	
Takigawa M.	瀧川村	35 33 13,6080 13,6164	– 0,0084	– 0,259	138 37 38,5880 38,5862	+ 0,0018	+ 0,045	0,263	170	
Inatumi M.	稻積村	35 36 33,1463 33,1458	– 0,0005	+ 0,015	138 33 20,8497 20,8520	– 0,0023	– 0,058	0,060	284	
Kyôto Y.	京戸山	35 37 17,8362 17,8522	– 0,0160	– 0,493	138 45 14,1798 14,1742	+ 0,0056	+ 0,151	0,516	163	

Table IV.—— Comparison of new and old geographic positions of secondary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New－Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New－Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kôun M.	甲運村	35 39 56,5169 56,5231	－ 0,0062	－ 0,191	138 37 45,3037 45,2985	＋ 0,0052	＋ 0,131	0,232	146	
Oohuzi M.	大藤村	35 42 12,3558 12,3716	－ 0,0158	－ 0,487	138 45 57,9683 57,9721	－ 0,0038	－ 0,095	0,496	191	
Tiyoda M.	千代田村	35 44 4,0381 4,0412	－ 0,0031	－ 0,096	138 35 52,9077 52,9014	＋ 0,0063	＋ 0,158	0,185	121	
Yanagisawatôge	柳澤峠	35 46 7,9838 7,9912	－ 0,0074	－ 0,228	138 47 52,1311 52,1385	－ 0,0074	－ 0,186	0,294	219	
Nakamaki M.	中牧村	35 46 41,9964 42,0035	－ 0,0071	－ 0,219	138 40 2,3800 2,3770	＋ 0,0030	＋ 0,075	0,231	161	
Kawazai	川　在	35 24 38,6732 38,6779	－ 0,0047	－ 0,145	140 9 40,4034 40,4010	＋ 0,0024	＋ 0,061	0,157	157	
Mariyatu	眞里谷	35 20 40,8330 40,8427	－ 0,0097	－ 0,299	140 7 52,7093 52,6966	＋ 0,0127	＋ 0,321	0,439	176	
Midunuma	水　沼	35 21 39,5256 39,5274	－ 0,0018	－ 0,055	140 12 45,3499 45,3456	＋ 0,0043	＋ 0,109	0,122	117	
Sakamoto	坂　本	35 23 49,8550 49,8522	＋ 0,0028	＋ 0,086	140 14 54,8961 54,8950	＋ 0,0011	＋ 0,028	0,090	18	
Sanuki	佐　貫	35 20 32,6166 32,6209	－ 0,0043	－ 0,133	140 16 56,2657 56,2534	＋ 0,0123	＋ 0,311	0,338	113	
Yamamoto	山　本	35 20 15,5292 15,5434	－ 0,0142	－ 0,438	140 4 7,7889 7,7678	＋ 0,0211	＋ 0,533	0,689	129	
Eikiti	永　吉	35 23 58,6794 58,6912	－ 0,0118	－ 0,364	140 3 24,6768 24,6622	＋ 0,0146	＋ 0,368	0,518	135	
Takinokuti	瀧ノ口	35 22 36,7316 36,7504	－ 0,0188	－ 0,579	140 0 23,1932 23,1735	＋ 0,0197	＋ 0,497	0,763	139	

Table IV.—— Comparison of new and old geographic positions of secondary triangulation points——contd.

Points	名 稱	New Latitudes Old Latitudes	Difference in second New – Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement		備 考
								$\sqrt{\Delta\varphi^2 + \Delta l^2}$	Direction from Old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Yokoyama	横 山	35 16 57,6209 57,6308	– 0,0099	– 0,305	140 12 24,3050 24,2874	+ 0,0176	+ 0,445	0,539	124	
Sugito	杉 戸	35 12 38,4669 38,4759	– 0,0090	– 0,277	140 17 7,3560 7,3373	+ 0,0187	+ 0,473	0,548	120	
Sakuta	作 田	35 17 30,2892 30,2965	– 0,0073	– 0,225	140 17 58,8782 58,8656	+ 0,0126	+ 0,318	0,390	125	
Takadani	高 谷	35 16 18,0306 18,0316	– 0,0010	– 0,031	140 21 18,3044 18,2952	+ 0,0092	+ 0,232	0,234	98	
Taitô	大 東	35 18 16,6106 16,6076	+ 0,0030	+ 0,092	140 24 55,4498 55,4517	– 0,0019	– 0,048	0,104	332	
Takayamada	高 山 田	35 12 8,6768 8,6816	– 0,0048	– 0,148	140 21 55,1322 55,1110	+ 0,0212	+ 0,536	0,556	105	
Matube	松 部	35 8 54,5290 54,5508	– 0,0218	– 0,672	140 17 2,4898 2,4674	+ 0,0224	+ 0,567	0,879	140	
Utiura	內 浦	35 7 35,7330 35,7582	– 0,0252	– 0,777	140 13 2,3256 2,2960	+ 0,0296	+ 0,749	1,079	136	
Sekiya	關 谷	35 10 15,2680 15,2836	– 0,0156	– 0,481	140 19 12,9455 12,9260	+ 0,0195	+ 0,493	0,689	134	
Inage	稻 毛	35 37 40,3795 40,3791	– 0,0156	– 0,481	140 5 26,9075 26,9135	– 0,0060	– 0,151	0,504	197	
Hunabasi	船 橋	35 41 19,8241 19,8392	– 0,0151	– 0,465	140 0 20,6081 20,6168	– 0,0087	– 0,219	0,514	205	
Matugasima	松 ケ 島	35 30 11,0938 11,0958	– 0,0020	– 0,062	140 4 11,5271 11,5218	+ 0,0053	+ 0,134	0,148	115	
Yawata	八 幡	35 32 23,9150 23,9162	– 0,0012	– 0,037	140 7 27,7212 27,7256	– 0,0044	– 0,111	0,117	252	

Table IV.—— Comparison of new and old geographic positions of secondary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Diffeernce in second New - Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Hukumasu	福増	35 28 32,9914 32,9926	− 0,0012	− 0,037	140 8 51,1353 51,1328	+ 0,0025	+ 0,063	0,073	120	
Osinuma	押沼	35 31 49,6448 49,6430	+ 0,0018	+ 0,055	140 11 55,1566 55,1678	− 0,0112	− 0,282	0,287	281	
Miyama	三山	35 41 47,6659 47,6796	− 0,0137	− 4,422	140 3 44,3492 44,3586	− 0,0094	− 0,236	0,483	209	
Iriyamazu	不入斗	35 26 45,4517 45,4604	− 0,0087	− 0,268	140 3 30,8808 30,8712	+ 0,0096	+ 0,242	0,361	138	
Nakatakane	中高根	35 26 35,5658 35,5729	− 0,0071	− 0,219	140 6 44,8248 44,8184	+ 0,0064	+ 0,161	0,272	144	
Sakao	坂尾	35 35 40,1304 40,1360	− 0,0056	− 0,173	140 10 54,3570 54,3760	− 0,0190	− 0,478	0,508	250	
Minamigyotoku	南行德	35 39 52,5578 52,5702	− 0,0124	− 0,382	139 51 18,2876 18,2756	+ 0,0120	+ 0,302	0,487	142	

備考. 新舊經緯度の欄中＿＿部ハ秘密地域の爲削除セルモノナリ

Remark : ——Blancks in columns of lalitudes and longitudes are due to the points being situated within the prohibied area.

Table V.—Comparison of new and old geographic positions of tertiary triangulation points

Point	名 稱	New Latitudes Old Latitudes	Difference in secoed New - Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備 考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Adumabasi.	吾妻橋	35 42 21,103 21,133	− 0,030	− 0,925	139 48 8,515 8,504	+ 0,011	+ 0,276	0,965	174	
Atago Y.	愛宕山	35 39 41,828 41,856	− 0,028	− 0,863	139 45 7,040 7,050	− 0,010	− 0,252	0,899	196	
Honmuratyô	本村町	35 38 53,984 54,015	− 0,031	− 0,955	139 44 1,580 1,589	− 0,009	− 0,226	0,981	193	
Honmaru.	本丸	35 41 6,014 6,044	− 0,030	− 0,925	139 45 28,406 28,419	− 0,013	− 0,427	1,019	205	
Itigaya.	市ヶ谷	35 41 19,446 19,473	− 0,027	− 0,832	139 44 1,141 1,148	− 0,007	− 0,176	0,850	192	
Ootuka.	大塚	35 42 47,630 47,658	− 0,028	− 0,863	139 44 0,337 0,348	− 0,011	− 0,276	0,906	198	
Daigaku.	大學	35 42 33,132 33,162	− 0,030	− 0,925	139 45 49,108 49,119	− 0,011	− 0,276	0,970	197	
Sunamura.	砂村	35 39 55,977 55,971	+ 0,006	+ 0,185	139 50 27,632 27,649	− 0,017	− 0,428	0,466	293	
Nibandaiba.	二番臺場	35 37 36,829 36,856	− 0,027	− 0,833	139 46 2,532 2,530	+ 0,002	+ 0,030	0,833	178	
Sanbandaiba.	二番臺場	35 37 50,603 50,627	− 0,024	− 0,740	139 46 34,542 34,542	0,000	0,000	0,740	180	

Table V.—— Comparison of new and old geographic positions of tertiray triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New−Old	Diffeaence in length Δφ	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2 + \Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m		″	″	m	°	
Yodobasi.	淀橋	35 41 22,240 22,260	− 0,020	− 0,616	139 42 1,355 1,367	− 0,012	− 0,302	0,686	206	
Simomuradôri.	下村通	35 36 12,191 12,223	− 0,032	− 0,986	130 42 45,656 45,657	− 0,001	− 0,025	0,986	180	
Hunabori.	船堀	35 40 49,166 49,178	− 0,012	− 0,370	139 52 30,266 30,253	+ 0,013	+ 0,327	0,494	139	
Sisibone.	鹿骨	35 42 11,974 11,998	− 0,024	− 0,740	139 53 59,957 59,950	+ 0,007	+ 0,176	0,761	167	
Issiki.	一色	35 42 45,172 45,193	− 0,021	− 0,647	139 52 36,774 36,776	− 0,002	− 0,050	0,649	185	
Kameari.	龜有	35 45 37,477 37,493	− 0,016	− 0,493	139 51 26,088 26,092	− 0,004	− 0,100	0,503	192	
Midumoto.	水元	35 46 53,432 53,441	− 0,009	− 0,277	139 52 18,064 18,066	− 0,002	− 0,050	0,281	190	
Nisiarai.	西新井	35 46 59,171 59,181	− 0,010	− 0,308	139 46 42,963 42,965	− 0,002	− 0,052	0,312	190	
Simonerima.	下練馬	35 44 12,608 12,634	− 0,026	− 0,801	139 39 41,735 41,740	− 0,005	− 0,126	0,811	189	
Hatinari.	八成	35 43 26,373 26,398	− 0,025	− 0,770	139 37 14,606 14,612	− 0,006	− 0,151	0,785	191	
Nakakubo.	中久保	35 40 17,342 17,370	− 0,028	− 0,863	139 37 17,264 17,268	− 0,004	− 0,101	0,869	187	
Yôga.	用賀	35 37 25,500 25,534	− 0,034	− 1,048	139 38 33,339 33,338	+ 0,001	+ 0,025	1,048	179	
Komazawa M.	駒澤村	35 37 55,164 55,197	− 0,033	− 1,017	139 40 6,499 6,499	0,000	0,000	1,017	180	

Table V.—— Comparison of new and old geographic positions of tertiray triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New – Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Senzoku.	洗　足	35 36 14,122 14,158	– 0,036	– 1,109	139 41 53,234 53,232	+ 0,002	+ 0,050	1,110	176	
Oomori.	大　森	35 34 56,212 56,245	– 0,033	– 1,017	139 43 32,381 32,383	– 0,002	– 0,066	1,019	181	
Hanezawa.	羽　澤	35 39 59,195 59,225	– 0,030	– 0,925	139 32 36,179 36,161	+ 0,018	+ 0,327	0,981	133	
Takaisi.	高　石	35 35 51,358 51,401	– 0,043	– 1,325	129 31 26,472 26,469	+ 0,003	+ 0,076	1,327	177	
Tatibana.	橘	35 35 32,678 32,720	– 0,042	– 1,294	139 36 42,600 42,592	+ 0,008	+ 0,201	0,309	171	
Ikuta.	生　田	35 36 17,566 17,609	– 0,043	– 1,325	139 33 29,236 29,234	+ 0,002	+ 0,050	1,326	178	
Eda.	荏　田	35 33 22,140 22,184	– 0,044	– 1,356	139 32 40,071 40,057	+ 0,014	+ 0,353	1,401	165	
Usikubo.	牛久保	35 33 33,469 33,514	– 0,045	– 1,387	139 34 41,368 41,354	+ 0,014	+ 0,353	1,431	166	
Kitano.	北　野	35 39 36,498 36,528	– 0,030	– 0,925	139 34 48,534 48,536	– 0,002	– 0,050	0,926	183	
Izumi.	和　泉	35 37 51,252 51,291	– 0,039	– 1,202	139 34 23,276 23,278	– 0,002	– 0,050	1,203	183	
Noge.	野　毛	35 36 6,298 6,336	– 0,038	– 1,171	139 38 46,681 46,677	+ 0,004	+ 0,065	1,173	177	
Hino.	日　野	35 40 29,102 29,142	– 0,040	– 1,233	139 23 36,404 36,399	+ 0,005	+ 0,126	1,239	174	
Misawa.	三　澤	35 39 4,729 4,770	– 0,041	– 1,263	139 25 38,694 38,692	+ 0,002	+ 0,050	1,264	173	

Table V.—— Comparison of new and old geographic posittons of tettiray triangulation points——contd.

Point	名　稱	New Latitudes	Difference in second	Difference in length	New Longitudes	Difference in second	Difference in length	Displacement		備考
		Old Latitudes	New − Old	$\Delta\varphi$	Old Longitudes	New − Old	Δl	$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kohigi.	小比金	35 38 41,725 41,765	− 0,040	− 1,233	139 20 10,757 10,751	+ 0,006	+ 0,151	1,242	173	
Kitaôtani.	北大谷	35 39 59,230 59,271	− 0,041	− 1,263	139 21 30,622 30,622	0,000	0,000	1,263	180	
Minamidaira.	南　平	35 38 44,767 44,808	− 0,041	− 1,263	139 23 55,510 55,502	+ 0,008	+ 0,201	1,279	171	
Motozyuku.	本　宿	35 40 4,108 4,142	− 0,034	− 1,048	139 27 35,830 35,832	− 0,002	− 0,050	1,049	183	
Daimaru.	大　丸	35 38 24,580 24,624	− 0,044	− 1,356	139 29 24,852 24,847	+ 0,005	+ 0,126	1,362	175	
Horinouti.	堀ノ内	35 38 1,733 1,775	− 0,042	− 1,294	139 22 38,788 38,780	+ 0,008	+ 0,201	1,309	171	
Aoyagi.	靑　柳	35 40 41,349 41,384	− 0,035	− 1,079	136 25 35,092 35,098	− 0,006	− 0,151	1,090	188	
Maruyama.	丸　山	35 38 27,952 27,994	− 0,042	− 1,294	139 26 48,524 48,520	+ 0,004	+ 0,101	1,298	176	
Gotentôge.	御殿峠	35 37 8,416 8,462	− 0,046	− 1,418	139 20 33,122 33,108	+ 0,014	+ 0,352	1,461	166	
Takatôge	高　峠	35 35 46,336 46,382	− 0,046	− 1,418	139 29 59,397 59,390	+ 0,007	+ 0,176	1,429	173	
Yamazaki.	山　崎	35 34 31,140 31,183	− 0,043	− 1,325	139 26 36,867 36,856	+ 0,011	+ 0,277	1,353	168	
Koyamada.	小田山	35 31 54,898 54,943	− 0,045	− 1,387	139 24 38,400 38,386	− 0,014	− 0,352	1,431	194	
Koyama.	小　山	35 36 7,002 7,047	− 0,045	− 1,387	139 21 54,450 54,437	+ 0,013	+ 0,327	1,425	167	

Table V.—— Comparison of new and old géographic positions of tertiary triangulation points——contd.

Point	名 稱	New Latitudes Old Latitudes	Difference in second Old – New	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second Old – New	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2 + \Delta l^2}$	Displacement Direction from old position, clockwise from north
		° ′ ″	″	m	° ′ ″	″	m	m	°
Eti.	依 知	35 30 26,502 26,553	– 0,051	– 1,572	139 21 56,970 56,940	+ 0,030	+ 0,756	1,744	154
Kamimizo.	上 溝	35 33 4,306 4,358	– 0,052	– 1,602	136 22 16,678 16,657	+ 0,021	+ 0,529	1,687	162
Sannôduka.	山王塚	35 36 18,368 18,414	– 0,046	– 1,418	139 23 52,852 52,837	+ 0,015	+ 0,378	1,468	165
Otiai.	落 合	35 37 27,364 27,411	– 0,047	– 1,448	139 25 13,354 13,348	+ 0,006	+ 0,191	1,461	172
Oosawa.	大 澤	35 36 8,482 8,527	– 0,045	– 1,387	139 25 46,396 46,388	+ 0,008	+ 0,201	1,401	172
Nakatu.	中 津	35 31 30,744 30,794	– 0,050	– 1,541	139 20 31,670 31,646	+ 0,024	+ 0,605	1,656	159
Hutinobe.	淵野邊	35 33 42,696 42,745	– 0,049	– 1,510	139 24 12,094 12,071	+ 0,023	+ 0,579	1,617	169
Santa M.	散田村	35 38 29,609 29,655	– 0,046	– 1,418	139 18 49,366 49,349	+ 0,017	+ 0,428	1,481	163
Kamikunugita M.	上椚田村	35 37 56,727 56,774	– 0,047	– 1,448	139 16 55,536 55,521	+ 0,015	+ 0,377	1,496	165
Tatugo.	龍 子	35 36 0,989 1,037	– 0,048	– 1,479	139 16 47,584 47,569	+ 0,015	+ 0,378	1,530	166
Aihara M.	相原村	35 35 12,558 12,607	– 0,049	– 1,510	139 19 38,826 38,809	+ 0,017	+ 0,428	1,569	164
Ogura Y.	小倉山	35 34 2,131 2,183	– 0,052	– 1,602	139 17 49,933 49,911	+ 0,022	+ 0,554	1,695	172
Mikuri.	三栗山	35 32 28,164 28,217	– 0,053	– 1,633	139 18 52,332 52,306	+ 0,026	+ 0,655	1,759	158

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名 稱	New Latitudes	Difference in second	Difference in Length	New Longitudes	Difference in second	Difference in length	Displacement		
		Old Latitudes	New – Old	$\Delta\varphi$	Old Longitutdes	New - Old	Δl	$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwsie from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Amagoi D.	雨乞岳	35 33 11,972 12,025	– 0,053	– 1,633	139 16 38,160 38,142	+ 0,018	+ 0,456	1,695	164	
Irisawa.	入 澤	35 35 59,020 59,073	– 0,053	– 1,633	139 15 31,302 31,286	+ 0,016	+ 0,403	1,682	166	
Nagamine.	永 峰	35 32 32,757 32,812	– 0,055	– 1,695	139 14 19,712 19,625	+ 0,087	+ 2,191	2,770	128	
Aonohara M.	靑野原村	35 33 19,686 19,740	– 0,054	– 1,664	139 12 59,819 59,791	+ 0,028	+ 0,705	1,807	167	
Yamamiti.	山 道	35 34 38,165 38,217	– 0,052	– 1,603	139 12 12,916 12,891	+ 0,025	+ 0,629	1,722	159	
wakayanagi M.	若柳村	35 36 29,942 29,988	– 0,046	– 1,418	139 12 6,791 6,784	+ 0,007	+ 0,176	1,429	173	
Magoyama.	孫 山	35 37 24,919 24,963	– 0,044	– 1,356	139 11 26,426 26,403	+ 0,023	+ 0,579	1,474	167	
Hiture M.	日蓮村	35 36 10,749 10,789	– 0,040	– 1,233	139 10 30,056 30,026	+ 0,030	+ 0,755	1,445	149	
Kyôduko.	九曜塚	35 39 30,443 30,486	– 0,043	– 1,325	136 17 51,656 51,638	+ 0,018	+ 0,453	1,401	161	
Karasawa.	柄 澤	35 31 2,262 2,315	– 0,053	– 1,733	139 15 40,624 40,601	+ 0,023	+ 0,580	1,827	161	
Yakata Y.	屋形山	35 31 1,138 1,188	– 0,050	– 1,541	139 17 56,205 56,181	+ 0,024	+ 0,605	1,655	169	
Yamanokami.	山ノ神	35 31 44,058 44,100	– 0,042	– 1,294	139 12 50,900 50,862	+ 0,038	+ 0,957	1,609	144	
Kuzuhara M.	葛原村	35 35 38,892 38,935	– 0,043	– 1,325	139 8 40,509 40,477	+ 0,032	+ 0,805	1,550	149	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Andizawa M. (1)	安寺澤村(一)	35 33 5,918 5,968	− 0,050	− 1,541	139 7 12,166 12,126	+ 0,040	+ 1,008	1,841	147	
Tomioka M.	富岡村	35 34 1,155 1,198	− 0,043	− 1,325	139 7 55,134 55,099	+ 0,035	+ 0,881	1,591	146	
Sekirôsantyô.	石老山頂	35 34 55,403 55,450	− 0,047	− 1,448	139 11 32,934 32,906	+ 0,028	+ 0,705	1,611	154	
Nakaôkuwa M.	中大桑村	35 34 47,777 47,823	− 0,046	− 1,418	139 9 52,672 52,640	+ 0,032	+ 0,806	1,631	150	
Toya M. (1)	鳥屋村(一)	35 32 8,161 8,212	− 0,051	− 1,572	139 11 34,088 34,050	+ 0,038	+ 0,957	1,840	149	
Higasino M.	東野村	35 32 19,578 19,628	− 0,050	− 1,542	139 8 44,904 44,869	+ 0,035	+ 0,882	1,776	150	
Aonemura. (1)	青根村(一)	35 31 23,213 23,263	− 0,050	− 1,542	139 9 7,968 7,933	+ 0,035	+ 0,882	1,776	150	
Aonemura. (3)	青根村(三)	35 30 27,495 27,543	− 0,048	− 1,479	139 7 45,922 45,883	+ 0,039	+ 0,983	1,776	146	
Toya M. (4)	鳥屋村(四)	35 30 36,781 36,832	− 0,051	− 1,572	139 11 0,740 0,709	+ 0,031	+ 0,781	1,755	154	
Toya M. (6)	鳥屋村(六)	35 31 15,800 15,848	− 0,048	− 1,479	139 11 58,383 58,343	+ 0,040	+ 1,008	1,790	146	
Nanakunitôge.	七國峠	35 36 37,574 37,618	− 0,044	− 1,356	139 19 10,502 10,492	+ 0,010	+ 0,252	1,379	169	
Oosima.	大　島	35 33 53,278 53,330	− 0,052	− 1,602	139 19 46,714 46,693	+ 0,021	+ 0,529	1,687	162	
Miyôdin Y.	神明山	—— ——	− 0,052	− 1,602	—— ——	+ 0,038	+ 0,960	1,868	149	房總地方

Table V.—— Comparison of new and old geographic positions of tertiary triangulatihn points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference In second New - Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2 + \Delta l}$	Displacement Direction from old position clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Terayama.	寺　山	—— ——	– 1,036	– 1,109	—— ——	+ 0,035	+ 0,884	1,418	141	房總地方
Nisidani.	西　谷	—— ——	– 0,032	– 0,986	—— ——	+ 0,033	+ 0,834	1,293	140	
Namimatu.	竝　松	35 19 5,738 5,767	– 0,029	– 0,894	139 57 34,560 34,528	+ 0,032	+ 0,808	1,205	138	〃
Nagaisi.	長　石	35 18 23,616 23,636	– 0,020	– 0,616	140 0 45,512 45,482	+ 0,030	+ 0,758	0,977	129	
Tukahara.	塚　原	35 17 35,502 35,527	– 0,025	– 0,770	139 58 54,982 54,952	+ 0,030	+ 0,758	1,080	135	
Tekoduka.	手子塚	35 21 17,270 17,290	– 0,020	– 0,616	139 55 1,876 1,855	+ 0,021	+ 0,530	0,813	139	
Takadukadai.	高塚臺	35 20 26,960 26,988	– 0,028	– 0,813	139 56 30,148 30,117	+ 0,031	+ 0,783	1,129	136	
Hutamatagawa.	二俣川	35 28 7,254 7,304	– 0,050	– 1,541	139 31 58,050 58,013	+ 0,037	+ 0,933	1,803	149	
Ipponmatu.	一本松	35 28 32,240 32,289	– 0,049	– 1,510	139 37 33,692 33,667	+ 0,025	+ 0,630	1,636	157	
Tobe.	戸　部	35 26 32,885 32,935	– 0,050	– 1,541	139 37 36,357 36,321	+ 0,036	+ 0,908	1,789	149	
Simo.	下	35 24 58,404 58,464	– 0,060	– 1,849	139 38 7,290 7,244	+ 0,046	+ 1,160	2,183	148	
Gyôzadani.	行座谷	35 27 28,499 28,552	– 0,053	– 1,633	139 34 20,882 20,848	+ 0,034	+ 0,857	1,844	152	
Wakagata.	若　方	35 30 44,506 44,543	– 0,037	– 1,140	139 42 50,409 50,391	+ 0,018	+ 0,454	1,227	133	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement		備　考
								$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Minami.	南	35 31 6,460 6,506	− 0,046	− 1,418	139 36 34,600 34,581	+ 0,019	+ 0,480	1,497	161	
Matubara.	松　原	35 29 1,512 1,560	− 0,048	− 1,479	139 34 49,275 49,247	+ 0,028	+ 0,706	1,642	154	
Tôbô.	東　方	35 31 10,647 10,691	− 0,044	− 1,352	139 35 4,484 4,467	+ 0,017	+ 0,429	1,418	162	
Sanya.	三　谷	35 29 46,592 46,644	− 0,052	− 1,602	139 31 38,790 38,758	+ 0,032	+ 0,806	1,793	153	
Suganuma.	菅　沼	35 31 11,508 11,554	− 0,046	− 1,418	139 32 39,303 39,282	+ 0,021	+ 0,529	1,513	160	
Takaduka.	高　塚	35 26 31,564 31,620	− 0,056	− 1,726	139 30 56,788 56,746	+ 0,042	+ 1,059	2,025	148	
Nakata.	中　田	35 25 6,128 6,188	− 0,060	− 1,849	139 30 52,551 52,507	+ 0,044	+ 1,110	2,157	149	
Miyakoduka.	都　塚	35 26 24,504 24,560	− 0,056	− 1,726	139 32 28,276 28,238	+ 0,038	+ 0,958	1,974	151	
Nakazato.	中　里	35 32 0,594 0,645	− 0,051	− 1,572	139 31 36,811 36,788	+ 0,023	+ 0,579	1,675	160	
Hassyûmi.	八州見	—— ——	− 0,075	− 2,311	—— ——	+ 0,058	+ 1,465	2,736	141	三浦半島
Nisitani.	西　谷	35 22 22,496 22,565	− 0,069	− 2,126	139 33 53,610 53,563	+ 0,047	+ 1,186	2,434	161	
Yamazaki.	山　崎	35 20 5,034 5,111	− 0,077	− 2,373	139 31 38,366 38,309	+ 0,057	+ 1,439	2,775	149	
Mukôyama.	向　山	35 25 16,488 16,546	− 0,058	− 1,787	139 33 23,210 23,170	+ 0,040	+ 1,009	2,052	150	

Table V.—— Comparison of new and old geographic positions of tertiary triangulasion points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New - Old	Difference in length Δφ	New Longitudei Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement: Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Nagatani.	永谷	35 23 57,641 57,708	− 0,067	− 2,064	139 34 56,004 55,961	+ 0,043	+ 1,085	2,332	161	
Gumisawa.	汲澤	35 23 44,330 44,392	− 0,062	− 1,911	139 31 8,308 8,264	+ 0,044	+ 1,110	2,210	150	
Takayama.	高山	35 23 14,180 14,246	− 0,066	− 2,033	139 32 51,298 55,252	+ 0,046	+ 1,161	2,341	150	
Sibatai.	柴臺	—— ——	− 0,074	− 2,281	—— ——	+ 0,051	+ 1,288	2,620	151	三浦半島
Sugita.	杉田	—— ——	− 0,085	− 2,619	—— ——	+ 0,046	+ 1,161	2,865	156	〃
Ootuka.	大塚	35 23 49,044 49,108	− 0,064	− 1,972	139 36 30,650 30,607	+ 0,043	+ 1,085	2,250	151	
Tamura.	田村	35 21 44,398 44,465	− 0,067	− 2,064	139 21 45,664 45,582	+ 0,082	+ 2,070	2,924	135	
Utimodosi.	打戻	35 23 35,902 35,965	− 0,063	− 1,941	139 25 35,608 35,545	+ 0,063	+ 1,590	2,509	141	
Inari.	稻荷	35 21 15,872 15,944	− 0,072	− 2,219	139 27 47,468 47,403	+ 0,065	+ 1,641	2,760	144	
Suga.	須賀	35 18 50,656 50,705	− 0,049	− 1,510	139 22 0,286 0'191	+ 0,095	+ 2,400	2,836	122	
Miyayama.	宮山	35 23 13,092 13,152	− 0,060	− 1,849	139 23 24,312 24,242	+ 0,070	+ 1,767	2,558	136	
Simoeti.	下依知	35 28 13,225 13,279	− 0,054	− 1,664	139 22 10,240 10,201	+ 0,039	+ 0,983	1,933	149	
Minesita.	峰下	35 29 19,750 19,803	− 0,053	− 1,633	139 24 28,578 28,543	+ 0,035	+ 0,882	1,856	152	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New−Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New−Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement: Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Ootuka.	大塚	35 27 43,801 43,857	− 0,056	− 1,726	139 25 31,035 30,994	+ 0,041	+ 1,034	2,012	149	
Kawaraguti.	河原口	35 26 31,360 31,433	− 0,073	− 2,558	139 22 42,288 42,247	+ 0,041	+ 1,034	2,759	158	
Tomuro.	戸室	35 26 42,166 42,221	− 0,055	− 1,695	139 21 7,730 7,685	+ 0,045	+ 1,135	2,040	146	
Nakahara.	中原	35 28 10,904 10,960	− 0,056	− 1,726	139 27 53,081 53,039	+ 0,042	+ 1,058	2,024	148	
Takayama.	高山	35 29 11,772 11,824	− 0,052	− 1,602	139 29 58,885 58,947	− 0,062	− 1,083	2,238	224	
Simosidana.	下土棚	35 24 22,706 22,769	− 0,063	− 1,941	139 27 48,048 48,000	+ 0,048	+ 1,211	2,288	148	
Teranoue.	寺ノ上	35 26 23,470 23,529	− 0,059	− 1,818	139 23 18,371 18,326	+ 0,045	+ 1,135	2,143	148	
Kameino.	龜井野	35 23 2,769 2,834	− 0,065	− 2,003	139 28 55,773 55,721	+ 0,052	+ 1,312	2,395	147	
Kawana.	川名	35 19 29,522 29,605	− 0,083	− 2,558	139 29 44,444 44,381	+ 0,063	+ 1,591	3,012	148	
Nurumidu.	温水	35 25 41,267 41,325	− 0,058	− 1,787	139 21 0,838 0,784	+ 0,054	+ 1,362	2,247	143	
Hiradai.	平臺	35 20 44,799 44,850	− 0,051	− 1,572	139 11 13,066 13,030	+ 0,036	+ 0,909	1,816	150	
Itinosawa.	一ノ澤	35 25 32,838 32,886	− 0,048	− 1,479	139 10 5,256 5,217	+ 0,039	+ 0,938	1,779	146	
Rokutanbatake.	六反畑	35 22 59,006 59,050	− 0,044	− 1,356	139 11 26,144 26,096	+ 0,048	+ 1,213	1,819	138	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名 稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備 考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Hiruga D.	蛭ヶ岳	35 28 59,107 59,151	− 0,044	− 1,356	139 8 31,496 31,461	+ 0,035	+ 0,882	1,617	147	
Kegon.	華嵓山	35 29 35,785 35,840	− 0,055	− 1,695	139 17 25,275 25,241	+ 0,034	+ 0,857	1,899	153	
Kanazawa.	金澤	35 29 49,064 49,111	− 0,047	− 1,449	139 12 56,010 55,967	+ 0,043	+ 1,084	1,810	143	
Sarusima.	猿島	35 29 55,651 55,703	− 0,052	− 1,602	139 14 46,248 46,216	+ 0,032	+ 0,806	1,793	153	
Hemuro.	邊室	35 29 12,050 12,098	− 0,048	− 1,479	139 15 28,992 28,958	+ 0,034	+ 0,857	1,709	150	
Negisi.	根岸	35 28 21,776 21,824	− 0,048	− 1,479	139 16 41,498 41,464	+ 0,034	+ 0,857	1,709	150	
Nanasawadin-siya	七澤神社	35 27 22,082 22,131	− 0,049	− 1,510	139 16 30,006 29,971	+ 0,035	+ 0,882	1,748	150	
Ainamura.	愛名村	35 26 24,648 24,702	− 0,054	− 1,664	139 19 26,472 26,426	+ 0,046	+ 1,160	2,028	145	
Maruyama.	丸山	35 21 35,026 35,069	− 0,043	− 1,325	139 12 30,873 30,828	+ 0,045	+ 1,136	1,745	139	
Mukôyama.	向山	35 20 7,690 7,745	− 0,055	− 1,695	139 13 41,210 41,156	+ 0,054	+ 1,164	2,175	141	
Senzyôdiki.	千疊敷	35 22 6,911 6,957	− 0,046	− 1,418	139 14 47,175 47,123	+ 0,052	+ 1,312	1,932	137	
Obaradai.	小原臺	35 22 50,470 50,534	− 0,064	− 1,972	139 13 32,194 32,143	+ 0,051	+ 1,287	2,354	147	
Hanakaito.	花開戸	35 24 27,526 27,577	− 0,051	− 1,572	139 12 54,425 54,377	+ 0,048	+ 1,212	1,985	142	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New - Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Sainokawara.	賽ノ河原	35 25 27,042 27,089	− 0,047	− 1,448	139 12 16,408 16,364	+ 0,044	+ 1,110	1,824	142	
Mukôbara.	向　原	35 20 43,099 43,151	− 0,052	− 1,602	139 16 47,562 47,497	+ 0,065	+ 1,641	2,293	134	
Tubouti.	坪　内	35 23 32,980 33,029	− 0,049	− 1,510	139 16 42,112 42,062	+ 0,050	+ 1,262	1,968	140	
Tomioka.	富　岡	35 24 38,289 38,341	− 0,052	− 1,602	139 18 38,858 38,801	+ 0,057	+ 1,438	2,153	138	
Otihada.	落　幡	35 22 26,720 26,769	− 0,049	− 1,510	139 16 46,074 46,018	+ 0,056	+ 1,413	2,068	137	
Sakama.	坂　間	35 20 18,004 18,063	− 0,059	− 1,818	139 18 16,405 16,328	+ 0,077	+ 1,944	2,661	133	
Hiyakudan.	百　段	35 23 19,181 19,233	− 0,052	− 1,602	139 18 26,315 26,253	+ 0,062	+ 1,564	2,239	136	
Taninomae.	谷ノ前	35 28 15,562 15,613	− 0,051	− 1,572	139 20 23,205 23,167	+ 0,038	+ 0,958	1,841	149	
Inokoisitôge.	イノコイシ峠	35 29 31,524 31,567	− 0,043	− 1,325	139 4 41,464 41,424	+ 0,040	+ 1,008	1,665	143	
Nakagawa. (6)	中川村（六）	35 27 29,901 29,936	− 0,035	− 1,079	139 3 20,852 20,795	+ 0,057	+ 1,437	1,797	127	
Oono Y.	大野山	35 22 57,773 57,810	− 0,037	− 1,140	139 3 6,762 6,715	+ 0,047	+ 1,187	1,645	134	
Isidana.	石　棚	35 27 36,110 36,166	− 0,056	− 1,726	139 5 21,800 21,738	+ 0,062	+ 1,563	2,329	138	
Oosugi Y.	大杉山	35 25 58,736 58,786	− 0,050	− 1,541	139 4 14,912 14,847	+ 0,065	+ 1,639	2,250	133	

Tadle V.—— Comparison of new and old geographic positions of tertjaay trirngulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from nroth	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kawamura. (2)	川　村（二）	35 21 6,318 6,362	− 0,044	− 1,356	139 5 0,438 0,393	+ 0,045	+ 1,136	1,769	140	
Muramatu Y.	村松山	35 21 41,496 41,546	− 0,050	− 1,541	139 7 0,028 6 59,980	+ 0,048	+ 1,212	1,960	142	
Kawamura. (3)	川　村（三）	35 22 15,385 15,423	− 0,038	− 1,171	139 4 56,555 56,506	+ 0,049	+ 1,237	1,703	133	
Sannokaya.	三ノ萱	35 26 25,901 25,952	− 0,051	− 1,572	139 8 40,486 40,458	+ 0,028	+ 0,708	1,724	156	
Hinokidake.	檜　岳	35 25 41,238 41,281	− 0,043	− 1,325	139 7 8,862 8,814	+ 0,048	+ 1,211	1,850	138	
Kurinokimiti.	栗ノ木道	35 25 16,428 16,470	− 0,042	− 1,294	139 8 58,870 58,821	+ 0,049	+ 1,236	1,817	136	
Kurokura M.	玄倉村	35 24 25,041 25,055	− 0,014	− 0,431	139 5 10,608 10,591	+ 0,017	+ 0,429	0,608	135	
Sidango.	シダンゴ	35 24 18,480 18,521	− 0,041	− 1,263	139 7 36,007 35,960	+ 0,047	+ 1,186	1,732	137	
Karasawa D.	唐澤岳	35 23 48,692 48,736	− 0,044	− 1,356	139 9 10,886 10,845	+ 0,041	+ 1,034	1,705	143	
Dairokuten.	大六天	35 22 43,084 43,121	− 0,037	− 1,140	139 7 18,972 18,925	+ 0,047	+ 1,186	1,645	134	
Ooninba.	大荷場	35 21 22,838 22,878	− 0,040	− 1,233	139 8 52,692 52,658	+ 0,034	+ 0,858	1,502	145	
Sinokubo M.	篠窪村	35 20 46,938 46,982	− 0,044	− 1,356	139 9 56,824 56,790	+ 0,034	+ 0,858	1,605	148	
Itibasita.	市場下	35 19 43,474 43,520	− 0,046	− 1,418	139 9 22,226 22,193	+ 0,033	+ 0,833	1,645	150	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement: Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kaizawa.	貝澤	35 19 42,134 42,171	− 0,037	− 1,140	139 5 17,888 17,953	− 0,065	− 1,641	1,998	235	
Oono.	大野	35 18 38,433 38,463	− 0,030	− 0,925	135 3 18,492 18,446	+ 0,046	+ 1,162	1,485	129	
Sumimuki M.	炭向山	35 18 3,116 3,158	− 0,042	− 1,294	139 6 57,270 57,247	+ 0,023	+ 0,581	1,418	156	
Midunosita.	水ノ下	35 17 10,885 10,914	− 0,029	− 0,894	139 4 28,840 28,805	+ 0,035	+ 0,884	1,257	135	
Ipponmatu.	一本松	35 16 30,232 30,278	− 0,046	− 1,418	139 8 32,922 32,863	+ 0,059	+ 1,491	2,058	134	
Tawaraisi.	俵石	35 16 19,424 19,445	− 0,021	− 0,647	139 2 7,738 7,702	+ 0,036	+ 0,910	1,116	125	
Igiriyasiki.	亥切屋敷	35 15 25,311 25,345	− 0,034	− 1,048	139 6 8,753 8,728	+ 0,025	+ 0,632	1,222	122	
Myôzyô D.	明星岳	35 15 9,778 9,808	− 0,030	− 0,925	139 4 14,317 14,291	+ 0,026	+ 0,657	1,135	145	
Kawanisi M. (3)	川西村(三)	35 21 55,758 55,799	− 0,041	− 1,263	139 3 10,890 10,844	+ 0,046	+ 1,161	1.716	137	
Iwase.	岩瀬	— —	− 0,054	− 1,664	— —	+ 0,042	+ 1,061	1,973	147	房總地方
Kinada Y.	鬼泪山	— —	− 0,042	− 1,294	— —	+ 0,035	+ 0,884	1,567	146	
Yamanokami.	山ノ神	— —	− 0,053	− 1,633	— —	+ 0,043	+ 1,087	1,962	146	
Sirokoma.	白駒	35 16 59,782 59,813	− 0,031	− 0,955	139 57 41,754 41,721	+ 0,033	+ 0,834	1,268	139	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points ——contd.

Point	名稱	New Latitude Old Latitudes	Difference in second New—Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Mineyama.	峰山	— —	− 0,040	− 1,233	— —	+ 0,032	+ 0,809	1,475	147	房總地方
Mine.	峰	— —	− 0,054	− 1,664	— —	+ 0,042	+ 1,062	1,974	147	〃
Matugadai.	松ヶ臺	— —	− 0,049	− 1,510	— —	+ 0,039	+ 0,986	1,803	147	〃
Saga Y.	嵯峨山	— —	− 0,066	− 2,034	— —	+ 0,037	+ 0,936	2,239	155	〃
Tawara.	田原	— —	− 0,050	− 1,541	— —	+ 0,040	+ 1,012	1,844	147	〃
Uritu.	賣津	— —	− 0,065	− 2,003	— —	+ 0,045	+ 1,138	2,304	150	〃
Seri.	芹	35 13 22,949 22,983	− 0,034	− 1,048	139 58 54,546 54,509	+ 0,037	+ 0,936	1,405	138	
Tyôsaku.	長作	35 15 43,337 43,358	− 0,021	− 0,647	139 58 40,649 40,606	+ 0,043	+ 1,807	1,265	120	
Takamizo.	高溝	35 12 2,258 2,296	− 0,038	− 1,171	139 57 40,752 40,711	+ 0,041	+ 1,037	1,564	137	
Ueno.	上野	35 15 34,336 34,357	− 0,021	− 0,647	140 1 40,248 40,214	+ 0,034	+ 0,860	1,076	127	
Suzusinomatu.	凉ノ松	35 13 54,951 54,980	− 0,029	− 0,894	140 0 42,540 42,504	+ 0,036	+ 0,910	1,276	135	
Harayama.	原山	35 14 59,676 59,690	− 0,014	− 0,431	140 6 47,706 47,673	+ 0,033	+ 0,834	0,939	118	
Tanoyama.	田ノ山	— —	− 0,071	− 2,188	— —	+ 0,047	+ 1,189	2,449	152	房總地方

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	difference in second New - Old	difference in length $\Delta\varphi$	New Longitudes Old Longitudes	difference in second New – Old	difference in length Δl	Displacement $\sqrt{\Delta\varphi^2 + \Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	*m*	° ′ ″	″	*m*	*m*	°	
Tôgeduka	峠塚	— —	– 0,074	– 2,280	— —	+ 0,046	+ 1,164	2,560	153	〃
Monomiduka	物見塚	— —	– 0,070	– 2,157	— —	+ 0,041	+ 1,037	2,393	154	〃
Oonodai	火野臺	35 16 14,554 14,580	– 0,026	– 0,801	140 0 15,767 15,734	+ 0,033	+ 0,834	1,156	134	
Nakasawa	中澤	35 13 8,032 8,074	– 0,042	– 1,294	139 5 56,764 56,723	+ 0,041	+ 1,037	1,658	141	
Tukigemine	月毛峰	35 12 43,204 43,224	– 0,020	– 0,616	140 5 4,536 4,492	+ 0,044	+ 1,113	1,272	119	
Motokiyosumi	元清澄	35 10 19,130 19,152	– 0,022	– 0,678	140 5 57,572 57,522	+ 0,05$_0$	+ 1,264	1,434	105	
Utizumi	打墨	35 9 3,361 3,382	– 0,021	– 0,647	140 5 34,572 34,523	+ 0,049	+ 1,239	1,398	117	
Simidu	清水	35 11 22,009 22,030	– 0,021	– 0,647	140 4 18,222 18,176	+ 0,046	+ 1,164	1,332	119	
Komatimine	小町峰	35 8 34,723 34,747	– 0,024	– 0,740	140 3 0,582 0,537	+ 0,045	+ 1,139	1,358	124	
Higasikuti	東口	35 10 36,058 36,084	– 0,026	– 0,801	140 2 47,252 47,213	+ 0,039	+ 0,987	1,271	128	
Sanbongi	三本木	35 12 25,774 25,804	– 0,030	– 0,925	140 0 56,860 56,822	+ 0,038	+ 0,961	1,334	134	
Uenohara	上ノ原	35 11 41,442 41,469	– 0,027	– 0,832	140 2 16,183 16,143	+ 0,040	+ 1,012	1,310	129	
Tuboi	坪井	35 10 20,148 20,176	– 0,028	– 0,863	140 0 7,226 7,185	+ 0,041	+ 1,037	1,349	130	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	difference in second New – Old	difference in length $\Delta\varphi$	New Longitudes Old Longitudes	difference in second New – Old	difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Terakado	寺　門	35 8 3,506 3,536	– 0,030	– 0,925	140 0 27,648 27,608	+ 0,040	+ 1,012	1,407	132	房總地方
Toyooka	豊　岡	— —	– 0,036	– 1,109	— —	+ 0,039	+ 0,987	1,484	138	〃
Ooyama	大　山	— —	– 0,039	– 1,202	— —	+ 0,032	+ 0,810	1,449	146	
Gotôgyô	五頭鄉	35 10 10,018 10,064	– 0,046	– 1,418	139 56 50,217 50,179	+ 0,038	+ 0,961	1,713	146	房總地方
Yamanaka	山　中	— —	– 0,048	– 1,479	— —	+ 0,031	+ 0,785	1,674	152	〃
Hutatu	二	— —	– 0,054	– 1,664	— —	+ 0,028	+ 0,709	1,809	157	三浦半島
Hueta	笛　田	— —	– 0,081	– 2,496	— —	+ 0,057	+ 1,440	2,882	150	〃
Tendaisan	天臺山	— —	– 0,077	– 2,373	— —	+ 0,060	+ 1,515	2,815	147	〃
Takuma	宅　間	— —	– 0,086	– 2,650	— —	+ 0,061	+ 1,541	3,065	150	〃
Kotubo	小　坪	— —	– 0,088	– 2,712	— —	+ 0,062	+ 1,566	3,132	150	〃
Numama	沼　間	— —	– 0,083	– 2,558	— —	+ 0,058	+ 1,465	2,948	150	〃
Sanbu	三　分	— —	– 0,078	– 2,404	— —	+ 0,073	+ 1,843	3,029	143	〃
Muronoki	室　木	— —	– 0,083	– 2,558	— —	+ 0,054	+ 1,365	2,900	152	〃

Table V.—— Comparison of new and old gaographic positions of tertiary triangulation points ——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement		備　考
								$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Nagaura	長　浦	=	− 0,086	− 2,650	=	+ 0,056	+ 1,415	3,004	152	三浦半島
Hatakeyama	畠　山	=	− 0,092	− 2,835	=	+ 0,057	+ 1,440	3,181	153	〃
Simoyamaguti	下山口	=	− 0,082	− 2,527	=	+ 0,058	+ 1,466	2,921	153	〃
Akiya	秋　谷	=	− 0,094	− 2,897	=	+ 0,052	+ 1,315	3,181	156	〃
Kugô	公　鄉	=	− 0,092	− 2,835	=	+ 0,054	+ 1,365	3,146	154	〃
Zyômine	城　峰	=	− 0,093	− 2,866	=	+ 0,053	+ 1,340	3,164	118	〃
Koyagaya	小矢谷	=	− 0,092	− 2,835	=	+ 0,047	+ 1,188	3,074	157	〃
Deguti	出　口	=	− 0,109	− 3,359	=	+ 0,042	+ 1,063	3,523	162	〃
Hayasi	林	=	− 0,098	− 3,020	=	+ 0,050	+ 1,264	3,274	157	〃
Takahara	高　原	=	− 0,095	− 2,928	=	+ 0,054	+ 1,365	3,231	154	〃
Daihara	臺　原	=	− 0,101	− 3,113	=	+ 0,048	+ 1,214	3,340	159	〃
Mito	三　戸	=	− 0,112	− 3,452	=	+ 0,036	+ 1,038	3,605	163	〃
Kawama	川　間	=	− 0,094	− 2,897	=	+ 0,049	+ 1,239	3,151	156	〃

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New – Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New – Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m		
Kaneda	金田	—	– 0,115	– 3,544	—	+ 0,037	+ 0,936	3,666	165	〃
Tomari	泊	—	– 0,086	– 2,650	—	+ 0,058	+ 1,466	3,029	151	〃
Nobi	野比	—	– 0,095	– 2,928	—	+ 0,046	+ 1,163	3,152	158	〃
Simomiyata	下宮田	—	– 0,114	– 3,513	—	+ 0,040	+ 1,012	3,656	167	〃
Nisiya	西谷	—	– 0,086	– 2,650	—	+ 0,053	+ 1,340	2,970	153	〃
Moroiso	諸磯	—	– 0,118	– 3,636	—	+ 0,034	+ 0,861	3,737	98	〃
Zyôgasima	城ケ島	—	– 0,121	– 3,729	—	+ 0,031	+ 0,785	3,811	99	〃
Takatori Y.	鷹取山	35 19 33,678 33,738	– 0,060	– 1,849	139 16 42,782 42,714	+ 0,068	+ 0,717	2,316	147	
Kotake	小竹	35 18 58,872 58,925	– 0,053	– 1,633	139 14 10,191 10,137	+ 0,054	+ 1,364	2,128	140	
Yamanisi	山西	35 17 45,694 45,791	– 0,067	– 2,065	139 15 11,216 11,157	+ 0,059	+ 1,490	2,342	144	
Mandai	萬臺	35 18 45,291 45,359	– 0,068	– 2,095	139 17 25,822 25,744	+ 0,078	+ 1,970	2,876	136	
Karasubatake	烏畑	35 19 12,378 12,430	– 0,052	– 1,602	139 10 36,944 36,916	+ 0,028	+ 0,707	1,751	156	
Nagao Y.	長尾山	35 18 47,022 47,082	– 0,060	– 1,849	139 12 3,551 3,509	+ 0,042	+ 1,051	2,127	150	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New – Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New – Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kôdu	國府津	35 16 45,038 45,104	– 6,066	– 2,034	139 12 52,168 52,130	+ 0,038	+ 0,960	2,249	155	
Miyamukai Y.	宮向山	35 14 35,789 35,807	– 0,018	– 0,555	139 2 19,956 19,917	+ 0,039	+ 0,986	1,130	119	
Usibuse Y.	牛臥山	35 14 21,293 21,337	– 0,044	– 1,356	139 6 2,832 2,809	+ 0,023	+ 0,581	1,475	157	
Siroyama (2)	城山(2)	35 13 29,100 29,126	– 0,026	– 0,801	139 4 57,286 57,258	+ 0,028	+ 0,708	1,069	139	
Komaga T.	駒ヶ岳	35 13 11,118 11,137	– 0,019	– 0,586	139 1 51,456 51,421	+ 0,035	+ 0,885	1,061	124	
Wadanosumi	和田ノ角	35 12 53,326 53,339	– 0,013	– 0,401	139 0 30,400 30,371	+ 0,029	+ 0,733	0,835	119	
Hutago Y.	二子山	35 12 38,581 38,595	– 0,014	– 0,431	139 2 48,186 48,156	+ 0,030	+ 0,759	0,873	120	
Simoaito	下合戸	35 12 13,039 13,081	– 0,042	– 1,294	139 8 35,068 35,011	+ 0,057	+ 1,442	1,937	132	
Sirokane Y.	白銀山	35 11 53,508 53,539	– 0,031	– 0,955	139 4 39,114 39,077	+ 0,037	+ 0,936	1,337	136	
Byôbu Y.	屏風山	35 11 37,630 37,643	– 0,013	– 0,401	139 2 29,706 29,678	+ 0,028	+ 0,708	0,814	120	
Oosawa Y.	大澤山	35 11 8,039 8,066	– 0,027	– 0,832	139 6 1,658 1,630	+ 0,028	+ 0,708	1,092	140	
Minami yosihara	南吉原	35 10 42,584 42,630	– 0,046	– 1,418	136 7 43,990 43,952	+ 0,038	+ 0,961	1,713	146	
Tatusawa	立澤	35 10 38,446 38,469	– 0,023	– 0,709	139 4 20,437 20,407	+ 0,030	+ 0,759	1,039	133	

Table V.—— Comparison of new and old geographic positious of tertiary triangulation points——coutd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New－Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New Old	Difference in length Δl	Displacement		備考
								$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Nangô	南郷	35 10 24,300 24,355	－ 0,056	－ 1,726	139 6 27,326 27,304	＋ 0,022	＋ 0,557	1,814	162	
Kurakake Y.	鞍掛山	35 10 21,896 21,905	－ 0,009	－ 0,277	139 1 43,347 43,323	＋ 0,024	＋ 0,607	0,667	130	
Ueno	上野	35 9 31,412 31,457	－ 0,045	－ 1,387	139 4 55,635 55,616	＋ 0,019	＋ 0,481	1,468	161	
Karesugi	枯杉	35 9 19,108 19,125	－ 0,017	－ 0,524	139 2 58,138 58,111	＋ 0,027	＋ 0,683	0,861	127	
Tategakubo	立ヶ窪	35 8 11,107 11,139	－ 0,032	－ 0,986	139 6 39,426 39,409	＋ 0,017	＋ 0,430	1,076	156	
Umibira	海平	35 10 51,952 51,960	－ 0,008	－ 0,247	139 0 40,158 40,131	＋ 0,027	＋ 0,683	0,726	110	
Suwadai	諏訪臺	35 9 31,274 31,272	＋ 0,002	＋ 0,062	138 58 7,932 7,910	＋ 0,022	＋ 0,557	0,560	84	
Kamobora	賀茂洞	35 8 20,251 20,253	－ 0,002	－ 0,062	138 56 19,258 19,251	＋ 0,007	＋ 0,177	0,187	110	
Kuwahara M.	桑原村	35 7 27,260 27,268	－ 0,008	－ 0,247	138 59 36,558 36,540	＋ 0,018	＋ 0,456	0,519	118	
Kunimiisi	國見石	35 7 28,457 28,470	－ 0,013	－ 0,401	139 2 39,556 39,531	＋ 0,025	＋ 0,633	0,749	122	
Hatake M.	畑村	35 6 13,674 13,688	－ 0,014	－ 0,431	139 2 21,323 21,306	＋ 0,017	＋ 0,430	0,608	135	
Hirai M.	平井村	35 6 7,317 7,325	－ 0,008	－ 0,247	138 59 52,928 52,910	＋ 0,018	＋ 0,456	0,518	140	
Otiai	落合	35 14 45,263 45,271	－ 0,008	－ 0,247	138 58 39,701 39,664	＋ 0,037	＋ 0,936	0,968	105	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New – Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference iu second New Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Mikunitôge	三國峠	35 12 45,500 45,503	– 0,003	– 0,092	138 59 14,088 14,059	+ 0,029	+ 0,734	0,740	97	
Kendô	見洞	35 11 37,994 37,997	– 0,003	– 0,092	138 58 23,529 23,505	+ 0,024	+ 0,607	0,614	96	
Yamasitairi	山下入	35 11 19,872 19.867	+ 0,005	+ 0,154	138 56 16,113 16,100	+ 0,013	+ 0,329	0,363	65	
Siroyama	城山	35 8 52,070 52,073	– 0,003	– 0,092	138 59 44,890 44.871	+ 0,019	+ 0,481	0,490	101	
Idusan M.	伊豆山村	35 7 19,760 19,778	– 0,018	– 0,555	139 4 0,306 0,280	+ 0,026	+ 0,658	0,861	130	
Atami M. (1)	熱海村(一)	35 6 0,260 0,305	– 0,045	– 1,387	139 5 3,444 3,405	+ 0,039	+ 0,987	1, 02	125	
Atami M. (2)	熱海村(二)	35 4 55,078 55,100	– 0,022	– 0,678	139 4 38,678 38,657	+ 0,021	+ 0,532	0,861	142	
Oodai	大臺	—— ——	– 0,063	– 1,942	—— ——	+ 0,014	+ 0,355	1,974	169	房總地方
Enmyôzi	延命寺	—— ——	– 0,036	– 1,110	—— ——	+ 0,011	+ 0,279	1,145	171	〃
Konpira	金毘羅	—— ——	– 0,049	– 0,510	—— ——	+ 0,015	+ 0,380	1,557	169	〃
Okuyama	奥山	—— ——	– 0,052	– 1,603	—— ——	+ 0,010	+ 0,253	1,623	171	〃
Goten	御殿	—— ——	– 0,041	– 1,264	—— ——	+ 0,026	+ 0,659	1,425	152	〃
Takahata	高畑	—— ——	– 0,041	– 1,264	—— ——	+ 0,015	+ 0,380	1,320	161	〃

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New – Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New – Old	Difference in length Δl	Displacement		備考
								$\sqrt{\Delta\varphi^2 + \Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	m	m	° ′ ″	″	m	m	°	
Okinosima	沖　島	—— ——	– 0,067	– 2,065	—— ——	+ 0,009	+ 0,228	2,078	174	〃
Tomisan	富　山	—— ——	– 0,063	– 1,942	—— ——	+ 0,022	+ 0,557	2,020	165	〃
Tutumidani	堤　谷	—— ——	– 0,066	– 2,034	—— ——	+ 0,020	+ 0,507	2,096	112	〃
Isigami	石　神	—— ——	– 0,046	– 1,418	—— ——	+ 0,026	+ 0,658	1,563	155	〃
Hutatuyama	二ツ山	—— ——	– 0,035	– 0,079	—— ——	+ 0,029	+ 0,734	1,305	146	〃
Ootuka	大　塚	—— ——	– 0,065	– 2,003	—— ——	+ 0,009	+ 0,228	2,016	174	〃
Minamitokosiro	南床城	—— ——	– 0,069	– 2,127	—— ——	+ 0,012	+ 0,304	2,149	172	〃
Hasiragi	柱　木	—— ——	– 0,039	– 1,202	—— ——	+ 0,030	+ 0,760	1,422	148	〃
Nakanoiri	中野入	—— ——	– 0,028	– 0,863	—— ——	+ 0,014	+ 0,355	0,933	158	〃
Kamidai	上　臺	35 1 48,366 48,388	– 0,022	– 0,678	140 0 7,222 7,206	+ 0,016	+ 0,406	0,790	149	
Mituminesan	三峰山	—— ——	– 0,029	– 0,894	—— ——	+ 0,013	+ 0,329	0,953	160	房總地方
Hurukawa	古　川	—— ——	– 0,007	– 0,216	—— ——	+ 0,019	+ 0,481	0,527	114	〃
Kaminoyama	上ノ山	35 2 19,705 19,713	– 0,008	– 0,247	140 1 5,983 5,963	+ 0,020	+ 0,507	0,564	116	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Makado	眞　門	35 3 39,464 36,480	− 0,016	− 0,493	140 2 19,192 19,168	+ 0,024	+ 0,608	0,783	129	
Karasuba	烏　場	35 4 41,112 41,134	− 0,022	− 0,678	140 1 43,038 43,010	+ 0,028	+ 0,709	0,981	134	
Asamiduka	蒐　塚	35 6 5,014 5,039	− 0,025	− 0,770	140 3 17,762 17,721	+ 0,041	+ 1,038	1,292	127	
Issenzyô	一戰場	35 5 23,716 23,735	− 0,019	− 0,586	140 5 42,658 42,620	+ 0,038	+ 0,963	1,127	121	
Uehara	上　原	35 6 29,894 29,911	− 0,017	− 0,524	140 5 53,516 53,476	+ 0,040	+ 1,013	1,141	117	
Dôbone	胴　骨	35 5 10,962 10,994	− 0,032	− 0,986	140 0 21,201 21,172	+ 0,029	+ 0,735	1,230	143	
Hotokeduka	佛　塚	35 7 23,992 24,011	− 0,019	− 0,586	140 2 48,324 48,280	+ 0,044	+ 1,114	1,259	118	
Simidu	清　水	— —	− 0,061	− 1,880	— —	+ 0,023	+ 0,582	1,968	163	房總地方
Myôtoisi	女夫石	— —	− 0,060	− 1,849	— —	+ 0,016	+ 0,405	1,893	168	〃
Ukisima	浮　島	— —	− 0,084	− 2,589	— —	+ 0,027	+ 0,684	2,677	165	〃
Sengenyama	淺間山	35 7 36,944 36,963	− 0,019	− 0,586	140 5 22,222 22,178	+ 0,044	+ 1,114	1,259	118	
Yôizawa	用井澤	— —	− 0,073	− 2,250	— —	+ 0,033	+ 0,835	2,400	160	房總地方
Nemoto	根　本	35 7 49,959 49,980	− 0,021	− 0,647	140 7 23,520 23,476	+ 0,044	+ 1,114	1,288	120	

Table V.—— Comparison of new and old geogtaphic positions of tertiary triangulation points——contd.

Ponit	名 稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備 考
		° ′ ″	″		° ′ ″	″	m	m	°	
Okinasaku	翁 作	— —	− 0,061	− 1,880	— —	+ 0,025	+ 0,634	1,984	161	房總地方
Kayawatari	萱 渡	— —	− 0,051	− 1,572	— —	+ 0,024	+ 0,609	1,686	95	〃
Hunagasaku	船 ケ 作	— —	− 0,035	− 1,079	— —	+ 0,025	+ 0,634	1,251	150	〃
Aoyama	青 山	— —	− 0,030	− 0,925	— —	+ 0,014	+ 0,355	0,991	159	〃
Oosiba	大 芝	— —	− 0,046	− 1,418	— —	+ 0,016	+ 0,405	1,475	166	〃
Kenzyô	見 上	— —	− 0,044	− 0,356	— —	+ 0,019	+ 0,482	1,439	160	〃
Sirahama	白 濱	— —	− 0,027	− 0,832	— —	+ 0,026	+ 0,660	1,062	142	〃
Ooikura	大 井 倉	— —	− 0,019	− 0,586	— —	+ 0,025	+ 0,634	0,863	174	〃
Asinaga	足 長	— —	− 0,010	− 0,308	— —	+ 0,022	+ 0,558	0,637	119	〃
Mine Y.	峰 山	— —	− 0,008	− 0,247	— —	+ 0,023	+ 0,583	0,633	113	〃
Ootake	大 竹	— —	− 0,019	− 0,586	— —	+ 0,018	+ 0,456	0,743	143	〃
Yamamoto	山 本	— —	− 0,041	− 1,264	— —	+ 0,014	+ 0,355	0,313	164	〃
Tatuoka	龍 岡	— —	− 0,053	− 0,634	— —	+ 0,016	+ 0,406	1,684	166	〃

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New—Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New—Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	″	°	
Goi	五井	35 31 52,952 52,952	0,000	0,000	140 5 6,490 6,486	+ 0,004	+ 0,101	0,101	90	
Oosaku	大作	35 28 24,973 24,972	+ 0,001	+ 0,031	140 11 14,562 14,562	0,000	0,000	0,031	0	
Ogura	小倉	35 37 17,886 17,890	− 0,004	− 0,123	140 10 35,905 35,924	− 0,019	− 0,478	0,494	256	
Sanya	山谷	35 33 23,538 23,531	+ 0,007	+ 0,216	140 11 30,466 30,482	− 0,016	− 0,403	0,458	319	
Nisitera Y.	西寺山	35 38 55,488 55,500	− 0,012	− 0,370	140 8 6,362 6,370	− 0,008	− 0,201	0,421	209	
Yasaku	矢作	35 36 10,598 10,607	− 0,009	− 0,277	140 8 26,794 26,810	− 0,016	− 0,403	0,489	236	
Simonoseki	下ノ關	35 27 51,718 51,726	− 0,008	− 0,247	140 1 49,814 49,807	+ 0,007	+ 0,176	0,303	145	
Kaihoduka	海保塚	35 28 12,252 12,241	+ 0,011	+ 0,339	140 4 22,027 22,016	+ 0,011	+ 0,277	0,438	39	
Suwadai	諏訪臺	35 29 16,228 16,229	− 0,001	− 0,031	140 6 58,932 58,932	0,000	0,000	0,000	180	
Gokasyo	五ケ所	35 26 3,356 3,359	− 0,003	− 0,092	140 6 7,846 7,845	+ 0,001	+ 0,025	0,095	165	
Higasiyotutuzi	東四辻	35 30 22,203 22,201	+ 0,002	+ 0,062	140 8 51,123 51,122	+ 0,001	+ 0,025	0,067	22	
Sekisonsan	石尊山	35 27 11,833 11,834	− 0,001	− 0,031	140 9 23,825 23,824	+ 0,001	+ 0,025	0,040	141	
Kasiwai	柏井	35 40 52,834 52,843	− 0,009	− 0,277	140 6 46,212 46,219	− 0,007	− 0,176	0,328	212	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement: Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Takaya	高谷	35 41 49,500 49,519	− 0,019	− 0,586	139 56 29,684 29,686	− 0,002	− 0,050	0,588	185	
Saginuma	鷺沼	35 40 33,738 33,755	− 0,017	− 0,524	140 1 46,958 46,963	− 0,005	− 0,126	0,539	194	
Isimiya	石宮	35 43 27,675 27,704	− 0,029	− 0,894	139 5 2,834 2,813	+ 0,021	+ 0,528	1,038	149	
Matubai	松倍	35 43 0,216 0,245	− 0,029	− 0,894	139 7 20,188 20,170	+ 0,018	+ 0,452	1,002	153	
Midukubo	水久保	35 43 52,627 52,660	− 0,033	− 1,017	139 8 22,756 22,741	+ 0,015	+ 0,377	1,085	160	
Matokari Y.	馬頭苅山	35 44 18,754 18,787	− 0,033	− 1,017	139 10 5,452 5,437	+ 0,015	+ 0,377	1,085	160	
Togurasiro Y.	戸倉城山	35 43 20,950 20,983	− 0,033	− 1,017	139 12 3,913 3,902	+ 0,011	+ 0,276	1,055	165	
Kotu	小津	35 40 52,420 52,452	− 0,032	− 0,986	139 13 26,741 26,734	+ 0,007	+ 0,176	1,002	130	
Usukine Y.	臼杵山	35 42 11,734 11,770	− 0,036	− 1,110	139 10 6,871 6,855	+ 0,016	+ 0,402	1,181	160	
Ippoti	逸歩地	35 41 11,808 11,842	− 0,034	− 1,048	139 10 21,936 21,918	+ 0,018	+ 0,453	1,142	157	
Nakamure Y.	中牟札山	35 41 31,306 31,331	− 0,025	− 0,770	139 2 10,309 10,287	+ 0,022	+ 0,553	0,948	144	
Sengendaira	千軒平	35 42 47,610 47,632	− 0,022	− 0,678	139 1 59,135 59,114	+ 0,021	+ 0,528	0,859	92	
Inomaru	猪丸	35 41 24,109 24,138	− 0,029	− 0,894	139 5 16,000 15,978	+ 0,022	+ 0,553	1,051	148	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2 + \Delta l^2}$	Displacement Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	m	m	m	°	
Toya	戸　谷	35 41 37,563 37,593	− 0,030	− 0,925	139 7 15,192 15,171	+ 0,021	+ 0,528	1,065	130	
Konpira Y.	金平山	35 40 4,200 4,238	− 0,038	− 1,171	139 14 59,303 59,291	+ 0,012	+ 0,302	1,209	165	
Tenguduka	天狗塚	35 41 19,540 19,575	− 0,035	− 1,079	139 15 54,217 54,201	+ 0,016	+ 0,402	1,151	160	
Inume	犬　目	35 41 10,826 10,866	− 0,040	− 1,233	139 19 1,013 1,015	− 0,002	− 0,050	1,234	182	
Tobuki	戸　吹	35 42 29,825 29,859	− 0,034	− 1,048	139 16 55,907 55,893	+ 0,014	+ 0,352	1,106	161	
Siroyama	城　山	35 43 2,251 2,281	− 0,030	− 0,925	139 14 44,872 44,855	+ 0,017	+ 0,427	1,019	155	
Nibugata	二分方	35 40 19,574 19,611	− 0,037	− 1,140	139 16 52,575 52,561	+ 0,014	+ 0,352	1,193	163	
Kuwakubo M.	桑窪村	35 38 35,170 35,204	− 0,034	− 1,048	139 3 23,902 23,878	+ 0,024	+ 0,604	1,210	150	
Siozu M.	四方津村	35 36 54,584 54,626	− 0,042	− 1,294	139 5 14,342 14,317	+ 0,025	+ 0,629	1,439	154	
Nodazirieki	野田尻驛	35 37 43,040 43,076	− 0,036	− 1,110	139 4 15,958 15,938	+ 0,020	+ 0,503	1,219	156	
Wami M.	和見村	35 39 47,395 47,426	− 0,031	− 0,955	139 4 5,522 5,495	+ 0,027	+ 0,678	1,171	145	
Torisawa M.	鳥澤村	35 38 2,545 2,586	− 0,041	− 1,264	139 1 1,016 0,984	+ 0,032	+ 0,805	1,499	147	
Onokubo M.	斧窪村	35 36 17,010 17,044	− 0,034	− 1,048	139 1 41,016 40,980	+ 0,036	+ 0,906	1,385	139	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New - Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kobuse M.	小伏村	35 39 25,276 25,311	− 0,035	− 1,079	139 6 6,224 6,202	+ 0,022	+ 0,553	1,212	153	
Terasita M.	寺下村	35 34 59,158 59,196	− 0,038	− 1,171	139 4 12,897 12,865	+ 0,032	+ 0,805	1,421	146	
Daimaru Y.	大丸山	35 35 28,958 29,002	− 0,044	− 1,356	139 5 32,086 32,058	+ 0,028	+ 0,705	1,528	153	
Kamino M. (2)	神野村(二)	35 32 43,344 43,385	− 0,041	− 1,264	139 4 53,391 53,353	+ 0,038	+ 0,957	1,585	143	
Takagane	高ガ子	35 33 45,333 45,370	− 0,037	− 1,140	139 2 50,243 50.204	+ 0,039	+ 0,982	1,505	139	
Narayama	楢山	35 34 34,134 34,166	− 0,032	− 0,986	139 0 26,226 26,187	+ 0,039	+ 0,982	1,392	135	
Ookuri M.	大栗村	35 32 31,706 31,745	− 0,039	− 1,202	139 2 40,740 40,697	+ 0,043	+ 1,083	1,618	138	
Kawarata M.	河原畑村	35 31 30,314 30,354	− 0,040	− 1,233	139 0 33,614 33,574	+ 0,040	+ 1,008	1,593	141	
Ganyûdô	加入道	35 30 23,505 23,550	− 0,045	− 1,387	139 2 57,811 57,767	+ 0,044	+ 1,109	1,776	144	
Kagenobu Y.	景信山	35 38 33,967 34,008	− 0,041	− 1,264	139 13 8,620 8,612	+ 0,008	+ 0,201	1,280	171	
Dinbamine	陣場峰	35 38 56,147 56,186	− 0,039	− 1,202	139 10 11,114 11,095	+ 0,019	+ 0,478	1,294	158	
Nakura M.	名倉村	35 36 24,401 24,447	− 0,046	− 1,418	139 8 27,880 27,850	+ 0,030	+ 0,755	1,606	162	
Takatori Y,	高取山	35 37 51,972 52,011	− 0,039	− 1,202	139 8 5,971 5,947	+ 0,024	+ 0,604	1,345	153	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New—Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New Old	Difference in second Δl	Displacement		備考
								$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Nôtake Y.	能竹山	35 38 55,794 55,831	− 0,037	− 1,140	139 6 51,305 51,282	+ 0,023	+ 0,578	1,278	156	
Kunuginosawa	椚ノ澤	35 40 8,592 8,631	− 0,039	− 1,202	139 11 45,695 45,678	+ 0,017	+ 0,427	1,276	161	
Saimokuzawa	村木澤	35 38 48,470 48,514	− 0,044	− 1,356	139 14 43,437 43,425	+ 0,012	+ 0,302	1,389	167	
Kuitutô	クイツトウ	35 32 34,016 34,020	− 0,004	− 0,123	139 34 35,272 35,275	− 0,003	− 0,076	0,145	212	
Satogaki	里垣	35 39 58,030 58,032	− 0,002	− 0,062	138 35 1,368 1,367	+ 0,001	+ 0,025	0,067	158	
Bôgamine	坊ケ峰	35 35 46,403 46,406	− 0,003	− 0,092	138 36 55,908 55,901	+ 0,007	+ 0,176	0,199	118	
Kirikubo	切久保	35 35 59,798 59,809	− 0,011	− 0,339	138 41 18,214 18,216	− 0,002	− 0,050	0,343	188	
Uenotaira	上ノ平	35 41 44,502 44,514	− 0,012	− 0,370	138 40 53,792 53,794	− 0,002	− 0,050	0,373	186	
Oomiya	大宮	35 41 56,057 56,059	− 0,002	− 0,062	138 32 50,200 50,199	+ 0,001	+ 0,025	0,067	161	
Oogi Y.	扇山	35 44 23,921 23,931	− 0,010	− 0,308	138 44 15,891 15,896	− 0,005	− 0,126	0,333	202	
Tawaratuka	俵塚	35 38 46,471 46,483	− 0,012	− 0,370	138 42 38,946 38,948	− 0,002	− 0,050	0,373	188	
Awahosiba	粟干場	35 40 4,664 4,692	− 0,028	− 0,863	139 0 8,988 8,963	+ 0,025	+ 0,628	0,067	144	
Takenosawa	竹ノ澤	35 41 54,952 54,975	− 0,023	− 0,709	138 58 30,084 30,069	+ 0,015	+ 0,377	0,803	118	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New - Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New - Old	Difference in length Δl	Displacement		備　考
								$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Oobane	大羽根	35 42 58,087 58,112	− 0,025	− 0,770	139 0 9,130 9,112	+ 0,018	+ 0,452	+ 0,893	150	
Nakizaka	泣　坂	35 41 18,936 18,961	− 0,025	− 0,770	138 55 57,079 57,068	+ 0,011	+ 0,277	+ 0,818	160	
Ookaba	大　樺	35 41 29,764 29,791	− 0,027	− 0,832	138 53 46,331 46,318	+ 0,013	+ 0,327	+ 0,894	159	
Humoto Y.	麓　山	35 40 26,716 26,741	− 0,025	− 0,770	138 57 33,784 33,765	+ 0,019	+ 0,478	+ 0,906	148	
Hattyôzaka	八丁坂	35 42 34,148 34,172	− 0,024	− 0,740	138 56 5,689 5,679	+ 0,010	+ 0,251	+ 0,781	161	
Tuboya	坪　谷	35 41 48,112 48,136	− 0,024	− 0,740	139 0 2,977 2,958	+ 0,019	+ 0,478	+ 0,881	147	
Tukizawagasira	槻澤頭	35 39 30,760 30,782	− 0,022	− 0,678	138 51 9,756 9,741	+ 0,015	+ 0,377	+ 0,776	151	
Kurokawa	黑　川	35 36 50,850 50,864	− 0,014	− 0,431	138 47 48,842 48,824	+ 0,018	+ 0,453	+ 0,625	133	
Nyûdô Y.	入道山	35 36 39,743 39,745	− 0,011	− 0,339	138 49 44,772 44,741	+ 0,031	+ 0,780	+ 0,850	113	
Oosika Y.	大鹿山	35 37 38,151 38,170	− 0,019	− 0,586	138 49 33,384 33,368	+ 0,016	+ 0,403	+ 0,711	145	
Oono	大　野	35 38 28,784 28,803	− 0,019	− 0,586	138 50 57,340 57,326	+ 0,014	+ 0,352	+ 0,684	149	
Magi	眞　木	35 36 31,996 32,017	− 0,021	− 0,647	138 53 33,732 33,709	+ 0,023	+ 0,579	+ 0,868	138	
Daimaru	大　丸	35 37 21,546 21,572	− 0,026	− 0,801	138 54 30,578 30,551	+ 0,027	+ 0,679	+ 1,050	140	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名 稱	New Latiudes Old Latitudes	Difference in second New−Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New−Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備 考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Dekigaya	出來萱	35 38 1,626 1,645	− 0,019	− 0,586	138 52 35,782 35,767	+ 0,015	+ 0,377	0,697	147	
Nowaki	野 脇	35 39 35,030 35,054	− 0,024	− 0,740	138 53 10,678 10,667	+ 0,011	+ 0,277	0,790	160	
Torisawa	鳥 澤	35 36 35,595 35,626	− 0,031	− 0,955	138 59 57,746 57,711	+ 0,035	+ 0,881	1,299	137	
Okuyama	奥 山	35 38 55,568 55,597	− 0,029	− 0,894	138 55 37,246 37,232	+ 0,014	+ 0,352	0,961	159	
Asakawa	淺 川	35 39 16,042 16,071	− 0,029	− 0,894	138 58 32,565 32,541	+ 0,024	+ 0,604	1,079	146	
Simowada	下和田	35 38 5,597 5,629	− 0,032	− 0,986	138 59 3,038 3,009	+ 0,029	+ 0,729	1,225	144	
Nigioka M.	賑岡村	35 37 29,440 29,463	− 0,023	− 0,709	138 56 20,786 20,765	+ 0,021	+ 0,528	0,884	134	
Natukari M.	夏狩村	35 32 37,138 37,146	− 0,008	− 0,247	138 51 50,248 50,233	+ 0,015	+ 0,378	0,452	123	
Toyoda	豊 田	35 33 18,048 18,050	− 0,002	− 0,062	138 50 31,728 31,708	+ 0,020	+ 0,504	0,508	97	
Sindôtôge	新道峠	35 34 22,761 22,771	− 0,010	− 0,308	138 52 27,388 27,367	+ 0,021	+ 0,529	0,612	120	
Ozata Y.	小形山	35 34 58,174 58,192	− 0,018	− 0,555	138 54 18,328 18,312	+ 0,016	+ 0,403	0,686	144	
Siroyama	城 山	35 33 4,232 4,248	− 0,016	− 0,493	138 54 25,120 25,090	+ 0,030	+ 0,755	0,902	123	
Oide Y.	生出山	35 33 42,037 42,059	− 0,022	− 0,678	138 55 42,738 42,706	+ 0,032	+ 0,806	1,053	130	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement		備　考
								$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Denzyôgumi	殿上組	35 35 57,252 57,280	− 0,028	− 0,863	138 58 5,797 5,760	+ 0,037	+ 0,931	1,269	133	
Urikubo	瓜　窪	35 34 37,746 37,778	− 0,032	− 0,986	138 59 9,089 9,051	+ 0,038	+ 0,957	1,374	136	
Banba	馬　場	35 32 52,990 53,022	− 0,032	− 0,986	138 58 28,695 28,658	+ 0,037	+ 0,932	1,357	136	
Hirosato M.	廣里村	35 35 50,726 50,756	− 0,030	− 0,925	138 55 45,138 45,101	+ 0,037	+ 0,931	1,312	135	
Hatukari M.	初狩村	35 35 51,357 51,380	− 0,023	− 0,709	138 53 4,750 4,729	+ 0,021	+ 0,529	0,885	143	
Turugatoya	鶴ケ鳥屋	35 34 43,777 43,804	− 0,027	− 0,832	138 50 39,942 39,929	+ 0,013	+ 0,327	0,894	159	
Dusadaira	ヅサ平	35 34 17,774 17,792	− 0,018	− 0,555	138 48 37,729 37,695	+ 0,034	+ 0,856	1,020	123	
Kuronoda	黑野田	35 35 35,590 35,603	− 0,013	− 0,401	138 49 21,622 21,589	+ 0,033	+ 0,831	0,923	116	
Suriharitôge	擦針峠	35 35 51,942 51,956	− 0,014	− 0,431	138 46 19,665 19,642	+ 0,023	+ 0,579	0,722	127	
Hukuti M.	福地村	35 28 29,756 29,801	− 0,045	− 1,387	138 47 15,021 14,983	+ 0,038	+ 0,958	1,686	98	
Konpira Y.	金比羅山	35 29 36,188 36,210	− 0,022	− 0,678	138 46 7,695 7,664	+ 0,031	+ 0,782	1,035	104	
Hunatugumi	船津組	35 28 10,982 10,987	− 0,005	− 0,154	138 44 42,822 42,809	+ 0,013	+ 0,327	0,361	115	
Umanoriisi Y.	馬乗石山	35 31 14,832 14,842	− 0,010	− 0,308	138 45 32,330 32,321	+ 0,009	+ 0,227	0,383	144	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New – Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Differedce in second New – Old	Difference ih lergth Δl	Displacemont $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacemont Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Arakuragumi	新倉組	35 30 59,674 59,699	− 0,025	− 0,770	138 47 53,404 53,381	+ 0,023	+ 0,580	0,964	143	
Asumi M.	明見村	35 29 56,294 56,315	− 0,021	− 0,647	138 49 43,461 43,417	+ 0,044	+ 1,109	1,284	120	
Takasasu	高サス	35 28 12,096 12,111	− 0,015	− 0,462	138 49 51,138 51,092	+ 0,046	+ 1,160	1,249	112	
Karaotozawa	空音澤	35 28 54,948 54,968	− 0,020	− 0,616	138 52 9,578 9,540	+ 0,038	+ 0,958	1,139	123	
Matuyuwa	松　岩	35 30 17,082 17,110	− 0,028	− 0,863	138 51 31,898 31,855	+ 0,043	+ 1,084	1,386	129	
Kamikureti	上暮地	35 31 21,286 21,289	− 0,003	− 0,092	138 49 55,700 55,684	+ 0,016	+ 0,403	0,413	103	
Hedono	邊　殿	35 31 19,694 19,704	− 0,010	− 0,308	138 53 25,833 25,810	+ 0,023	+ 0,579	0,656	118	
Miyazawa	宮　澤	35 30 31,604 31,627	− 0,023	− 0,709	138 54 25,086 25,058	+ 0,028	+ 0,706	1,001	135	
Ootake Y.	大竹山	35 31 54,640 54,656	− 0,016	− 0,493	138 55 1,928 1,908	+ 0,020	+ 0,504	0,705	134	
Nizyûrokuya Y.	二十六夜山	35 31 27,737 27,760	− 0,023	− 0,709	138 57 00,008 56 59,971	+ 0,037	+ 0,931	1,170	127	
Siraidaira	白井平	35 28 17,725 17,761	− 0,036	− 1,110	138 58 22,010 21,936	+ 0,047	+ 1,185	1,624	133	
Yotuzawa	四ツ澤	35 29 50,163 50,180	− 0,017	− 0,523	138 57 45,366 45,333	+ 0,033	+ 0,832	0,983	122	
Ibarasima	茨　島	35 31 5,068 5,097	− 0,029	− 0,894	138 58 39,172 39,135	+ 0,037	+ 0,931	1,291	134	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old—New	Difference in second New—Old	Difference in length $\Delta\varphi$	New Longitudes old Longitudes	Difference in second New—Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Tozawa	戸澤	35 29 5,048 5,071	− 0,023	− 0,709	138 52 53,534 53,508	+ 0,026	+ 0,655	0,965	137	
Utinotôge	内野峠	35 28 11,996 12,020	− 0,024	− 0,740	138 53 34,508 34,473	+ 0,035	+ 0,882	1,151	130	
Misakatôge	三坂峠	35 33 20,253 20,271	− 0,018	− 0,555	138 46 33,823 33,802	+ 0,021	+ 0,529	0,767	126	
Kanegakubo	金ケ凹	35 32 28,248 28,274	− 0,026	− 0,801	138 47 12,048 12,026	+ 0,002	+ 0,554	0,974	145	
Nakagawa M.(7)	中川村(七)	35 27 6,826 6,868	− 0,042	− 1,294	139 1 52,146 52,096	+ 0,050	+ 1,261	1,807	136	
Tunotori Y.	角取山	35 23 10,778 10,800	− 0,022	− 0,678	138 53 42,118 42,074	+ 0,044	+ 1,112	1,302	119	
Nakano M. (4)	中野村(四)	35 25 51,646 51,664	− 0,018	− 0,555	138 51 27,761 27,722	+ 0,039	+ 0,984	1,130	119	
Nakano M. (2)	中野村(二)	35 24 28,545 28,570	− 0,025	− 0,770	138 55 15,901 15,855	+ 0,046	+ 1,161	1,393	124	
Nakano M. (6)	中野村(六)	35 25 46,845 46,868	− 0,023	− 0,709	138 55 46,490 46,459	+ 0.031	+ 0,782	1,056	132	
Nakano M. (7)	中野村(七)	35 26 50,034 50,062	− 0,028	− 0,863	38 54 16,195 16,159	+ 0,036	+ 0,908	1,253	134	
Yotuke M. (14)	世附村(一四)	35 27 4,272 4,304	− 0,032	− 1,048	138 57 2,584 2,539	+ 0,045	+ 1,135	1,545	133	
Minesakatôge	峰坂峠	35 24 0,450 0,479	− 0,029	− 0,894	138 59 54,412 54,364	+ 0,048	+ 1,211	1,505	126	
Yotuke M. (10)	世附村(一〇)	35 25 3,031 3,067	− 0,036	− 1,110	139 1 1,313 1,240	+ 0,073	+ 1,841	2,149	121	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes	Difference in secodd New−Old $\Delta\varphi$	Difference in length	New Longitudes	Difference in second New−Old	Difference in length Δl	Displacement		備考
		Old Latitudes			Old Longitudes			$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Yotuke M. (13)	世附村(三)	35 27 30,780 30,812	− 0,032	− 0,986	138 58 54,343 54,296	+ 0,047	+ 1,186	1,542	130	
Sannodan	三ノ段	35 27 30,232 30,244	− 0,012	− 0,370	138 44 57,594 57,575	+ 0,019	+ 0,479	0,605	128	
Tutimarubi	土丸尾	35 26 2,044 2,062	− 0,018	− 0,555	138 47 46,208 46,173	+ 0,035	+ 0,883	1,370	122	
Soratôge	空峠	35 26 12,894 12,915	− 0,021	− 0,647	138 49 56,012 55,964	+ 0,048	+ 1,211	1,373	119	
Demarubi	出丸尾	35 26 1,285 1,303	− 0,018	− 0,555	138 45 26,620 26,600	+ 0,020	+ 0,504	0,750	138	
Torinomune	鳥ノ胸	35 29 43,650 43,689	− 0,039	− 1,202	139 0 35,100 35,058	+ 0,042	+ 1,058	1,601	139	
Zyôgaotôge	ジョウ顔峠	35 28 17,153 17,208	− 0,045	− 1,387	139 0 38,943 38,896	+ 0,047	+ 1,185	1,824	127	
Azegamaru	アゼガ丸	35 28 29,096 29,135	− 0,039	− 1,202	139 2 7,260 7,217	+ 0,043	+ 1,084	1,618	138	
Higasihosoono	東細尾野	35 24 16,942 16,967	− 0,025	− 0,770	138 46 43,574 43,540	+ 0,034	+ 0,858	1,153	132	
Takamarubi	高丸尾	35 23 55,640 55.657	− 0,017	− 0,523	138 48 10,683 10,638	+ 0,045	+ 1,135	1,250	115	
Nakano M. (3)	中野村(三)	35 23 56,203 56,223	− 0,020	− 0,602	138 51 52,896 52,856	+ 0,040	+ 1,009	1,148	121	
Irisumi	入隅	35 23 28,130 18,146	− 0,016	− 0,493	138 50 17,614 17,575	+ 0,039	+ 0,984	1,101	118	
Hugyôga D.	不淨ヶ岳	35 22 56,718 56,753	− 0,035	− 1,079	138 45 3,466 3,450	+ 0,016	+ 0,404	1,152	105	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New−Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New−Old	Difference in length Δl	Dislacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Dislacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Nakahinata M.	中日向村	35 22 26,475 26,504	− 0,029	− 0,894	138 56 33,096 33,046	+ 0,050	+ 1,262	1,547	125	
Kawanisi M. (1)	川西村(一)	35 22 18,554 18,600	− 0,046	− 1,418	139 0 36,106 36,024	+ 0,082	+ 2,070	2,509	125	
Kohuzi	小富士	35 22 9,372 9,394	− 0,022	− 0,678	138 47 11,554 11,517	+ 0,037	+ 0,934	1,154	126	
Subasiri (1)	須走村(一)	35 21 48,598 48,619	− 0,021	− 0,647	138 52 40,982 40,948	+ 0,034	+ 0,858	1,079	127	
Yuhune M. (2)	湯船村(二)	35 21 44,099 44,090	+ 0,009	+ 0,277	138 58 20,833 20,803	+ 0,030	+ 0,757	0,806	70	
Yaga M. (1)	谷ケ村(一)	35 21 40,562 40,588	− 0,026	− 0,801	139 1 48,402 48,355	+ 0,047	+ 1,186	1,190	124	
Yôzawa M.	用澤村	35 21 14,012 14,031	− 0,019	− 0,586	138 54 38,659 38,618	+ 0,041	+ 1,035	1,189	130	
Yosikubo M. (1)	吉久保村(一)	35 20 35,542 35,574	− 0,032	− 0,986	138 57 28,624 28,564	+ 0,060	+ 1,515	1,808	123	
Subasiri (2)	須走村(二)	35 20 34,002 34,023	− 0,021	− 0,647	138 52 50,498 50,456	+ 0,042	+ 1,060	1,242	121	
Manaitadaira	爼　平	35 20 15,908 15,887	+ 0,021	+ 0,647	138 59 57,948 57,941	+ 0,007	+ 0,177	0,671	15	
Hursawa M.	古澤村	35 20 4,852 4,865	− 0,013	− 0,401	138 56 0,926 0,885	+ 0,041	+ 1,035	1,110	111	
Nakahata M.	中畑村	35 19 39,976 39,992	− 0,016	− 0,493	138 51 43,549 43,509	+ 0,040	+ 1,010	1,124	116	
Negiti	禰宜地	35 19 33,588 33,577	+ 0,018	+ 0,555	138 57 9,882 9,793	+ 0,089	+ 2,246	2,314	76	

Table V.—— Comparisou of new and old geographic positions of tertiaiy triongulation points——contd.

Point	名 稱	New Latitudes Old Latitudes	Differdnce in second New − Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement		備 考
								$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	*m*	° ′ ″	″	*m*	*m*	°	
Nagatuka	永 塚	35 19 3,394 3,394	0,000	0,000	138 55 4,119 4,060	+ 0,059	+ 1,490	1,490	90	
Iiduka	飯 塚	35 18 39,660 39,667	− 0,007	− 0,216	138 53 30,744 30,712	+ 0,032	+ 0,808	0,836	105	
Innomurazi	印野村次	35 18 30,655 30,651	+ 0,004	+ 0,123	138 47 40,291 40,263	+ 0,028	+ 0,707	0,718	80	
Inagoba	蝗 場	35 18 25,036 25,060	− 0,024	− 0,740	138 0 50,132 50,064	+ 0,068	+ 1,718	1,870	113	
Hukasawa M.	深 澤 村	35 17 59,480 59,482	− 0,002	− 0,062	138 58 35,798 35,750	+ 0.048	+ 1,212	1,214	93	
Binsenduka	便 船 塚	35 17 36,481 36,482	− 0,001	− 0,031	138 56 41,848 41,789	+ 0,059	+ 1,490	1,490	91	
Kintoki Y.	金 時 山	35 17 11,053 11,060	− 0,007	− 0,216	139 0 28,870 28,804	+ 0,066	+ 1,668	1,682	97	
Innomurasaru	印野村猿	35 16 50,164 50,164	0,000	0,000	138 48 15,342 15,322	+ 0,020	+ 0,505	0,505	90	
Maru D.	丸 岳	35 16 8,096 8,115	− 0,019	− 0,586	138 58 43,464 43,415	+ 0,049	+ 1,238	1,370	115	
Higasitanaka M.	東田中村	35 16 4,262 4,273	− 0.011	− 0,339	138 57 27,271 27,221	+ 0,050	+ 1,264	1,309	105	
Kamiba M.	神 場 村	35 15 56,774 56,794	− 0,020	− 0,602	138 53 38,548 38,512	+ 0,036	+ 0,910	1,091	123	
Oono	大 野	35 16 3,609 3,617	− 0,008	− 0,247	238 51 26,820 26,799	+ 0,021	+ 0,531	0,586	115	
Suyama M.	須 山 村	35 14 56,848 56,854	− 0,006	− 0,185	138 49 15,957 15,944	+ 0,013	+ 0,329	0,378	119	

Table V.—— Comparison of new and old geographic positions of tertiaiy triongulation points——contd.

Point	名稱	New Latitudes Old Latitude	Difference in second New−Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in secodd New−Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kinezaka	木根坂	35 13 19,491 19,483	+ 0,008	+ 0,247	138 53 55,512 55,499	+ 0,013	+ 0,329	0,411	53	
Oosawairi	大澤入	35 13 13,871 13,864	+ 0,007	+ 0,216	138 48 47,216 47,203	+ 0,013	+ 0,329	0,394	57	
Nagasaka	長坂	35 13 2,148 2,148	0,000	0,000	138 51 4,042 4,038	+ 0,004	+ 0,101	0,101	90	
Ikenotaira	池ノ平	35 11 54,926 54,926	0,000	0,000	138 50 25,676 25,680	− 0,004	− 0,101	0,101	270	
Minamiyama	南山	35 11 40,208 40,200	+ 0,008	+ 0,247	138 53 51,680 51,671	+ 0,009	+ 0,228	0,336	42	
Zyôrinzi M.	定輪寺村	35 11 3,480 3,476	+ 0,004	+ 0,123	138 52 57,768 57,765	0,000	0,000	0,123	0	
Asidakasan	愛鷹三	35 10 31,187 31,193	− 0,006	− 0,185	138 49 20,073 20,081	− 0,008	− 0,202	0,273	227	
Hatibudai	八分臺	35 10 4,226 4,220	+ 0,006	+ 0,185	138 52 41,879 41,879	0,000	0,000	0,185	0	
Takayama	高山	35 9 55,584 55,588	− 0,004	− 0,123	138 50 42,962 42,967	− 0,005	+ 0,125	0,175	225	
Akasakadai	赤坂臺	35 20 28,726 28,743	− 0,017	− 0,523	140 1 37,544 37,520	+ 0,024	+ 0,606	0,800	131	
Abeduka	阿部塚	35 22 16,183 16,200	− 0,017	− 0,523	140 1 50,938 50,918	+ 0,020	+ 0,505	0,728	137	
Ittyôme	一丁目	35 23 37,457 37,473	− 0,016	− 0,493	140 1 16,504 16,487	+ 0,017	+ 0,429	0,653	139	
Sinkaiba	新開場	35 24 58,949 58,962	− 0,013	− 0,401	140 1 59,698 59,685	+ 0,013	+ 0,328	0,513	141	

Table V.—— Comparison of new and old geographic positions of tertiaiy triongulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New - Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New – Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kagamigamine	鏡ヶ峯	35 24 57,542 57,559	– 0,017	– 0,523	139 59 26,165 26,150	+ 0,015	+ 0,378	0,645	145	
Takatiho	高千穗	35 23 11,032 11,053	– 0,021	– 0,647	139 58 42,329 42,311	+ 0,018	+ 0,454	0,790	145	
Minowada	蓑和田	35 25 18,944 18,963	– 0,019	– 0,586	139 57 54,962 54,944	+ 0,018	+ 0,454	0,741	142	
Tyôziduka	丁子塚	35 23 58,566 58,592	– 0,026	– 0,801	139 55 56,040 56,014	+ 0,026	+ 0,656	1,035	141	
Kumanokosi	熊野腰	35 21 41,274 41,299	– 0,025	– 0,770	139 57 53,613 53,590	+ 0,023	+ 0,581	0,965	143	
Kamitakane	上高根	35 25 21,408 21,419	– 0,011	– 0,339	140 5 53,560 53,549	+ 0,011	+ 0,277	0,438	141	
Kanazawadai	金澤臺	35 22 39,243 39,250	– 0,007	– 0,216	140 7 35,680 35,673	+ 0,007	+ 0,177	0,279	141	
Miyanosita	宮ノ下	35 22 32,066 32,080	– 0,014	– 0,431	140 4 11,974 11,958	+ 0,016	+ 0,404	0,591	137	
Tyôzukadai	丁塚臺	35 22 4,428 4,433	– 0,005	– 0,154	140 10 14,107 14,103	+ 0,004	+ 0,101	0,184	147	
Togosidai	戸越臺	35 23 12,538 12,544	– 0,006	– 0,185	140 9 9,866 9,862	+ 0,004	+ 0,101	0,211	151	
Kirigaya	桐ヶ谷	35 23 7,793 7,805	– 0,012	– 0,370	140 5 30,700 30,685	+ 0,015	+ 0,379	0,530	134	
Makuta	馬來田	35 21 14,328 14,339	– 0,011	– 0,339	140 6 18,020 18,007	+ 0,013	+ 0,328	0,472	136	
Mukôyama	向　山	35 18 42,894 42,912	– 0,018	– 0,555	140 2 31,067 31,038	+ 0,029	+ 0,733	0,919	127	

Table V.—— Comparison of new and old geographic positions of tertiaiy triongulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference id second New – Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in cecond New – Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	″	°	
Azumadani	東　谷	35 19 50,615 50,626	– 0,011	– 0,339	140 5 42,064 42,042	+ 0,022	+ 0,556	0,651	121	
Manekimatu	招　松	35 20 3,204 3,208	– 0,004	– 0,123	140 18 36,837 36,826	+ 0,011	+ 0,278	0,304	113	
Ooyagi	大谷木	35 22 4,970 4,972	– 0,002	– 0,062	140 18 57,394 57,386	+ 0,008	+ 0,202	0,211	107	
Hokke	法　華	35 23 54,184 54,181	+ 0,003	+ 0,092	140 16 49,704 49,704	0,000	0,000	0,092	0	
Dibiki	地　引	35 21 59,778 59,779	– 0,001	– 0,031	140 16 12,804 12,793	+ 0,011	+ 0,278	0,280	96	
Hôondi	報恩寺	35 22 25,188 25,187	+ 0.001	+ 0,031	140 14 22,677 22,672	+ 0,005	+ 0,126	0,130	66	
Satubo	佐　坪	35 20 45,564 45,567	– 0,003	– 0,092	140 15 4,148 4,137	+ 0,011	+ 0.278	0,293	108	
Oobuta	大部田	35 22 44,474 44,478	– 0,004	– 0,123	140 11 45,998 45,996	+ 0,002	+ 0,050	1,124	158	
Sekinoya	關ノ谷	35 23 47,866 47,865	+ 0,001	+ 0,031	140 13 22,724 22,722	+ 0,002	+ 0,050	0,059	58	
Itiba	市　場	35 24 20,694 20,695	– 0,001	– 0,031	140 11 28,512 28,513	– 0,001	– 0,025	0,040	212	
Myôraku	妙　樂	35 18 38,001 38,006	– 0,005	– 0,154	140 16 24,371 24,353	+ 0,018	+ 0,455	0,480	109	
Itino	市　野	35 19 7,725 7,732	– 0,007	– 0,216	140 13 46,684 46,672	+ 0,012	+ 0,303	0,372	126	
iH miya	日　宮	35 19 10,972 10,974	– 0,002	– 0,062	140 15 30,790 30,776	+ 0,014	+ 0,354	0,359	100	

Table V.—— Comparison of new and old geographic positions of tertiaiy triongulation points ——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New − Old	Differerce in length Δφ	New Longitudes Old Longitudes	Difference in second New − Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備 考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Honnoki	盆　木	35 19 4,196 4,202	− 0,006	− 0,185	140 17 30,479 30,468	+ 0,011	+ 0,278	0,334	124	
Toyama	富　山	35 19 56,150 56,156	− 0,006	− 0,185	140 10 8,139 8,132	+ 0,007	+ 0,177	0,256	96	
Satomi	里　見	35 19 1,238 1,245	− 0,007	− 0,216	140 9 15,984 15,970	+ 0,014	+ 0,354	0,415	121	
Akasaka	赤　坂	35 18 45,276 45,279	− 0,003	− 0,092	140 21 10,714 10,709	+ 0,005	+ 0,126	0,156	126	
Siigi	椎　木	35 19 18,553 18,553	0,000	0,000	140 23 5,976 5,977	− 0,001	− 0,025	0,025	353	
Iwakuma	岩　熊	35 19 35,940 35,944	− 0,004	− 0,123	140 19 47,030 47,022	+ 0,008	+ 0,202	0,236	121	
Heizô	平　藏	35 19 51,882 51,826	+ 0,056	+ 1,726	140 11 53,375 53,366	+ 0,009	+ 0,227	1,741	7	
Matuyamanodai	松山ノ臺	35 16 57,592 57,607	− 0,015	− 0,462	140 4 5,119 5,088	+ 0,031	+ 0,783	0,909	121	
Takatuka	高　塚	35 18 4,744 4,757	− 0,013	− 0,401	140 5 2,691 2,663	+ 0,028	+ 0,707	0,813	102	
Siroyama	城　山	35 16 59,147 59,158	− 0,011	− 0,339	140 5 56,185 56,157	+ 0,028	+ 0,708	0,785	137	
Hirayama	平　山	35 15 49,860 49,874	− 0,014	− 0,431	140 4 45,537 45,503	+ 0,034	+ 0,860	0,962	127	
Kamiseki	上　關	35 14 9,874 9,892	− 0,018	− 0,555	140 4 15,829 15,791	+ 0,038	+ 0,961	1,110	120	
Takinoue	瀧ノ上	35 14 30,025 30,044	− 0,019	− 0,586	140 2 42,850 42,815	+ 0,035	+ 0,885	1,061	123	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New – Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New – Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement: Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Kase	加勢	35 12 18,198 18,220	− 0,022	− 0,678	140 6 59,214 59,168	+ 0,046	+ 1,163	1,346	120	
Orikizawa	折木澤	35 13 49,752 49,769	− 0,017	− 0,524	140 6 47,525 47,487	+ 0,038	+ 0,961	1,095	119	
Hunako	舟子	35 17 18,401 18,409	− 0,008	− 0,247	140 15 37,640 37,622	+ 0,018	+ 0,455	0,518	118	
Hassei	八聲	35 16 6,712 6,723	− 0,011	− 0,339	140 15 45,108 45,091	+ 0,017	+ 0,430	0,548	110	
Haguro	羽黑	35 18 25,214 25,220	− 0,006	− 0,185	140 14 1,102 1,086	+ 0,016	+ 0,404	0,444	111	
Tukide	月出	35 18 1,370 1,379	− 0,009	− 0,277	140 10 10,714 10,698	+ 0,016	+ 0,404	0,490	124	
Ookubo	大久保	35 17 4,074 4,086	− 0,012	− 0,370	140 8 23,830 23,805	+ 0,025	+ 0,632	0,732	120	
Ogusabatake	小草畑	35 18 5,072 5,079	− 0,007	− 0,216	140 11 45,194 45,178	+ 0,016	+ 0,404	0,458	119	
Oritu	折津	35 16 17,328 17,341	+ 0,013	− 0,401	140 10 33,986 33,963	+ 0,023	+ 0,581	0,707	125	
Uehara	上原	35 16 27,276 27,286	− 0,010	− 0,308	140 13 55,175 55,158	+ 0,017	+ 0,429	0,528	126	
Ootuka	大塚	35 15 13,482 13,494	− 0,012	− 0,370	140 14 9,072 9,052	+ 0,020	+ 0,506	0,627	126	
Kamisiki	紙・敷	35 15 23,092 23,104	− 0,012	− 0,370	140 12 26,176 26,156	+ 0,020	+ 0,506	0,627	126	
Sugimori	杉森	35 14 0,791 0,673	+ 0,118	+ 3,637	140 13 4,828 4,762	+ 0,066	+ 1,668	4,001	25	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New – Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New – Old	Difference in length Δl	Displacement		備　考
								$\sqrt{\Delta\varphi^2 + \Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	m	
Simizu	清　水	35 14 31,842 31,858	− 0,016	− 0,493	140 9 37,954 37,924	+ 0,030	+ 0,758	0,904	123	
Ooyatu	大　谷	35 14 31,432 31,446	− 0,014	− 0,431	140 10 50,962 50,933	+ 0,029	+ 0,733	0,850	130	
Ibota	伊保田	35 13 13,974 13,986	− 0,012	− 0,730	140 11 34,512 34,483	+ 0,029	+ 0,734	0,759	117	
Unamago	宇那孫	35 11 43,810 43,827	− 0,017	− 0,524	140 10 19,762 19,721	+ 0,041	+ 1,037	1,162	117	
Takatenzin	高天神	35 10 0,578 0,597	− 0,019	− 0,586	140 9 56,418 56,374	+ 0,044	+ 1,113	1,258	118	
Hirasawa	平　澤	35 12 48,707 48,715	− 0,008	− 0,247	140 14 56,470 56,450	+ 0,020	+ 0,506	0,563	141	
Araki	荒　木	35 13 59,845 59,854	− 0,009	− 0,277	140 16 20,236 20,217	+ 0,019	+ 0,481	0,555	120	
Nisino	西　野	35 10 35,590 35,609	− 0,019	− 0,586	140 7 52,187 52,143	+ 0,044	+ 1,114	1,259	118	
Oomi	大　見	35 9 18,184 18,205	− 0,021	− 0,647	140 8 37,296 37,253	+ 0,043	+ 1,086	1,264	121	
Mukôseko	向　迫	35 16 4,311 4,324	− 0,013	− 0,401	140 8 6,868 6,840	+ 0,028	+ 0,709	0,815	119	
Una	宇　那	35 9 9,080 9,098	− 0,018	− 0,555	140 11 13,848 13,812	+ 0,036	+ 0,912	1,068	121	
Sinzaka	新　坂	35 7 7,350 7,373	− 0,023	− 0,709	140 11 10,756 10,720	+ 0,036	+ 0,912	1,155	128	
Suzuri	硯	35 7 58,093 58,116	− 0,023	− 0,709	140 8 47,854 47,812	+ 0,042	+ 1,063	1,278	124	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes Old Latitudes	Difference in second New – Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New—Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise fromn orth	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Hukusawa	福澤	35 8 39,813 39,832	– 0,019	– 0,586	140 13 8,711 8,678	+ 0,033	+ 0,835	1,020	125	
Ueno	上野	35 9 58,022 58,040	– 0,018	– 0,555	140 15 18,766 18,741	+ 0,025	+ 0,632	0,841	131	
Kusihama	串濱	35 9 34,447 34,465	– 0,018	– 0,555	140 18 0,333 0,314	+ 0,019	+ 0,481	0,734	139	
Yumiki	弓木	35 12 31,945 31,960	– 0,015	– 0,462	140 12 22,141 22,110	+ 0,031	+ 0,784	0,910	121	
Huzisu	藤須	35 11 3,434 3,451	– 0,017	– 0,524	140 11 42,661 42,624	+ 0,037	+ 0,936	1,073	119	
Okitu	興津	35 8 36,272 36,295	– 0,023	– 0,709	140 15 19,163 19,135	+ 0,028	+ 0,709	1,003	135	
Bettô	別當	35 11 57,998 58,011	– 0,013	– 0,401	140 15 37,756 37,735	+ 0,021	+ 0,531	0,665	127	
Ookusu	大楠	35 11 16,868 16,881	– 0,013	– 0,401	140 17 8,751 8,729	+ 0,022	+ 0,557	0,686	126	
Ogura	大倉	35 16 7,130 7,137	– 0,007	– 0,216	140 18 4,203 4,190	+ 0,013	+ 0,329	0,394	123	
Kazi	鍛冶	35 14 11,819 11,826	– 0,007	– 0,216	140 17 39,558 39,540	+ 0,018	+ 0,455	0,504	115	
Mangi	萬木	35 17 26,636 26,640	– 0,004	– 0,123	140 19 53,740 53,727	+ 0,013	+ 0,328	0,350	111	
Nakadaki	中瀧	35 17 23,574 23,577	– 0,003	– 0,092	140 22 34,706 34,704	+ 0,002	+ 0,051	0,105	151	
Katuura	勝浦	35 8 12,968 12,990	– 0,022	– 0,678	140 19 5,766 5,746	+ 0,020	+ 0,506	0,846	143	

Table V.—— Comparison öf new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes / Old Latitudes	Difference in sccond New—Old	Difference in length Δφ	New Longitudes / Old Longitudes	Difference in seccnd New—Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2 + \Delta l^2}$	Displacement Direction from old position, clockwise from north	備考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Hebara	部原	35 10 10,210 10,226	− 0,016	− 0,493	140 20 38,822 38,806	+ 0,016	+ 0,405	0,638	141	
Iwawada	岩和田	35 10 47,886 47,899	− 0,013	− 0,401	140 22 26,062 26,039	+ 0,023	+ 0,582	0,707	125	
Iwahune	岩船	35 12 5,199 5,200	− 0,001	− 0,031	140 23 34,562 34,535	+ 0,027	+ 0,683	0,684	93	
Ebita	蝦田	35 14 18,530 18,527	+ 0,003	+ 0,092	140 24 19,352 19,343	+ 0,009	+ 0,228	0,246	68	
Takatuka	高塚	35 14 30,979 30,985	− 0,006	− 0,185	140 21 28,796 28,780	+ 0,016	+ 0,404	0,444	115	
Sanmon	三門	35 16 15,801 15,806	− 0,005	− 0,154	140 22 42,766 42,761	+ 0,005	+ 0,126	0,199	141	
Hukabori	深塚	35 15 27,812 27,818	− 0,006	− 0,185	140 24 1,462 1,453	+ 0,009	+ 0,228	0,293	129	
Takayatu	竹谷	35 13 42,852 42,858	− 0,006	− 0,185	140 22 9,350 9,332	+ 0,018	+ 0,455	0,491	114	
Nagayatu	長谷	35 13 37,914 37,924	− 0,010	− 0,308	140 20 0,616 0,600	+ 0,016	+ 0,404	0,508	143	
Haga	芳賀	35 12 2,210 2,218	− 0,008	− 0,247	140 18 37,882 37,862	+ 0,020	+ 0,506	0,563	120	
Yamada	山田	35 14 51,712 51,718	− 0,006	− 0,185	140 19 41,785 41,772	+ 0,013	+ 0,329	0,377	119	
Zikkoku	實谷	35 11 28,066 28,077	− 0,011	− 0,339	140 20 10,579 10,562	+ 0,017	+ 0,429	0,546	128	
Nagasakadai	長坂臺	35 8 38,866 38,865	+ 0,001	+ 0,031	138 52 16,920 16,922	− 0,002	− 0,051	0,060	301	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名　稱	New Latitudes Old Latitudes	Difference in second New − Old	Difference in length $\Delta\varphi$	New Longitudes Old Longitudes	Difference in socond New − Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Okamiya M. (1)	岡宮村(一)	35 7 45,612 45,615	− 0,003	− 0,092	138 52 31,300 31,305	− 0,005	− 0,127	0,157	234	
Dôniwa M.	堂庭村	35 5 51,512 51,519	− 0,007	− 0,216	138 54 34,096 34,093	+ 0,003	+ 0,076	0,229	106	
Nisisawada M.	西澤田村	35 7 51,864 51,869	− 0,005	− 0,154	138 50 50,608 50,619	− 0,011	− 0,278	0,318	241	
Matunaga M.	松長村	35 6 47,976 47,980	− 0,004	− 0,123	138 49 34,106 34,115	− 0,009	− 0,228	0,259	242	
Numazu (1)	沼　津(一)	35 5 58,592 58,601	− 0,009	− 0,277	138 51 14,667 14,675	− 0,008	− 0,203	0,344	216	
Simokanuki M.	下香貫村	35 4 12,584 12,596	− 0,012	− 0,370	138 52 1,550 1,551	− 0,001	− 0,025	0,371	184	
Kasiwaya M.	柏谷村	35 4 38,493 38,504	− 0,011	− 0,339	138 57 51,036 51,027	− 0,009	+ 0,228	0,409	146	
Nakoya M. (1)	奈古谷村(一)	35 4 5,050 5,062	− 0,012	− 0,370	139 0 55,522 55,511	− 0,011	+ 0,279	0,463	143	
Ôoka M. (1)	大岡村(一)	35 6 25,090 25,095	− 0,005	− 0,154	138 53 7,093 7,095	− 0,002	− 0,051	0,162	198	
Kamitaga M. (1)	上多賀村(一)	35 3 56,474 56,489	− 0,015	− 0,462	139 4 31,350 31,334	+ 0,016	+ 0,405	0,614	139	
Yokkamati M.	四日町村	35 3 3,106 3,121	− 0,015	− 0,462	138 56 56,706 56,704	− 0,002	+ 0,051	0,465	174	
Nirayamamati	韮山町	35 2 53,610 53,627	− 0,017	− 0,524	138 58 38,846 38,840	+ 0,006	+ 0,152	0,546	164	
Simotaga M. (1)	下多賀村(一)	35 2 18,548 18,561	− 0,013	− 0,401	139 2 29,184 29,180	+ 0,004	+ 0,101	0,414	166	

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

Point	名稱	New Latitudes	Difference in second	Difference in length	New Longitudes	Difference in second	Difference in length	Displacement		備考
		Old Latitudes	New − Old	Δφ	Old Longitudes	New − Old	Δl	$\sqrt{\Delta\varphi^2+\Delta l^2}$	Direction from old position, clockwise from north	
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Ukihasi M. (1)	浮橋村(一)	35 2 8,109 8,120	− 0,011	− 0,339	139 0 16,277 16,274	+ 0.003	+ 0,076	0,347	167	
〃 (2)	浮橋村(二)	35 1 10,564 10,578	− 0,014	− 0,431	139 0 50,974 50,972	+ 0,002	+ 0,071	0,437	171	
Usami M. (1)	宇佐美村(一)	35 1 15,737 15,752	− 0,015	− 0,462	139 3 40,934 40,928	+ 0,006	+ 0,152	0,486	162	
Usami M. (2)	宇佐美村(二)	35 1 9,475 9,499	− 0,024	− 0,740	139 5 23,784 23,784	0,000	0,000	0,740	180	
Tozawa M.	戸澤村	35 1 58,120 58,130	− 0,010	− 0,308	138 54 55,353 55,352	+ 0,001	+ 0,025	0,309	112	
Takyô M.	田京村	35 0 49,742 49,755	− 0,013	− 0,401	138 57 47,758 47,759	− 0,001	− 0,025	0,402	183	
Hirasawa M.	平澤村	35 0 56,999 57,002	− 0,003	− 0,092	138 51 38,163 38,160	+ 0,003	+ 0,076	0,119	140	
Kuryo M. (1)	久料村(一)	35 1 0,859 0,861	− 0,002	− 0,062	138 49 33,864 33,857	+ 0,007	+ 0,177	0,188	109	
Omosu M.	重須村	35 0 3,210 3,215	− 0,005	− 0,154	138 53 34,020 34,018	+ 0,002	+ 0,051	0,162	162	
Oono M. (1)	大野村(一)	34 59 36,226 36,233	− 0,007	− 0,216	138 58 51,813 51,817	− 0,004	− 0,101	0,238	200	
Yunokawa M.(1)	湯川村(一)	—— ——	− 0,018	− 0,555	—— ——	− 0,003	− 0,076	0,560	188	伊豆地方
Isigami Y.	石上山	—— ——	− 0,008	− 0,247	—— ——	+ 0,003	+ 0,076	0,258	163	〃
Oka M. (1)	岡村(一)	—— ——	− 0,009	− 0,277	—— ——	− 0,002	− 0,051	0,282	190	〃

Table V.—— Comparison of new and old geographic positions of tertiary triangulation points——contd.

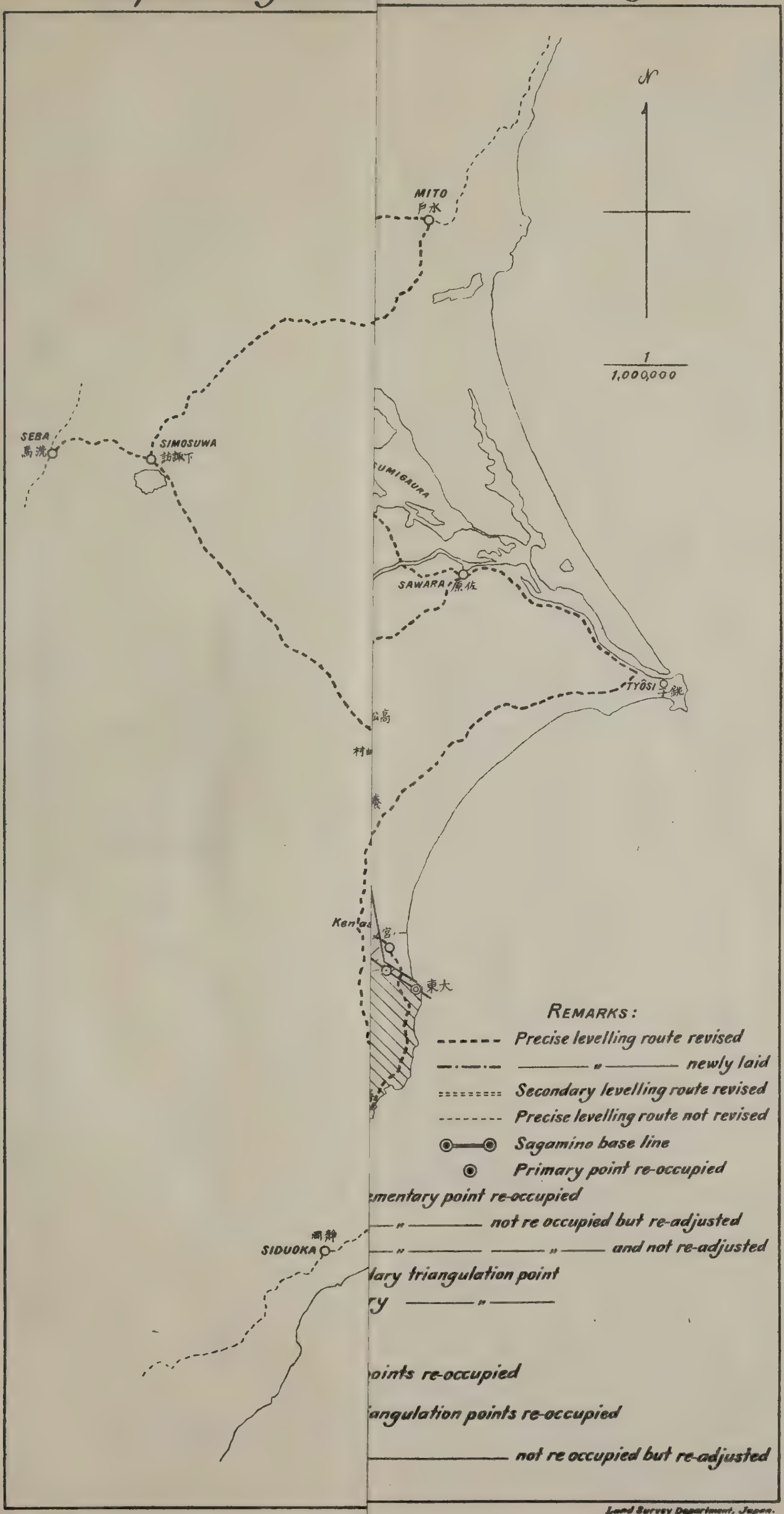
Point	名　稱	New Latitudes Old Latitudes	Difference in second New—Old	Difference in length Δφ	New Longitudes Old Longitudes	Difference in second New—Old	Difference in length Δl	Displacement $\sqrt{\Delta\varphi^2+\Delta l^2}$	Displacement Direction from old position, clockwise from north	備　考
		° ′ ″	″	m	° ′ ″	″	m	m	°	
Mukôyamano	向山野	34 59 7,700 7,702	− 0,002	− 0,062	138 47 51,266 51,265	+ 0,001	+ 0,025	0,067	158	
Kou M.	古宇村	34 58 51,732 51,738	− 0,006	− 0,185	138 49 47,718 47,714	+ 0,004	+ 0,102	0,211	151	
Sotoumizawa	外海澤	34 58 49,569 49,568	+ 0,001	+ 0,031	138 46 39,030 39,022	+ 0,008	+ 0,203	0,205	81	
Syûzenzi M. (1)	修善寺村(一)	34 58 40,734 40,735	− 0,001	− 0,031	138 56 27,103 27,106	− 0,003	− 0,076	0,082	248	
Kamisiraiwa M. (1)	上白岩村(一)	34 58 13,752 13,764	− 0,006	− 0,185	138 59 25,780 25,783	− 0,003	− 0,076	0,200	202	
〃 (2)	〃 (二)	34 56 53,618 53,613	+ 0,005	+ 0,154	138 58 59,796 59,799	− 0,003	− 0,076	0,172	334	
Osiba Y.	大芝山	34 58 21,246 21,249	− 0,003	− 0,092	138 52 18,176 18,175	+ 0,001	+ 0,025	0,095	165	
Isiharazawa	石原澤	34 57 52,375 52,377	− 0,002	− 0,062	138 50 21,220 21,218	+ 0,002	+ 0,051	0,080	141	
Myôno	妙　野	34 56 30,524 30,519	+ 0,005	+ 0,154	138 48 7,662 7,657	+ 0,005	+ 0,127	0,200	39	
Himori M.	日守村	35 3 40,888 40,903	− 0,015	− 0,462	138 55 43,286 43,282	+ 0,004	+ 0,101	0,473	168	

備考. 新舊經緯度ノ欄中 ＿＿ 部ハ秘密地域ノ爲削除セルモノナリ.

Remark :——Blanks in columns of lalitudes and longitudes are due to the points being situated within the prohibited area.

Map showing the D District & Vicinity.

Pl. I



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Ken
宮
大東
SIDUOKA
靜岡
REMARKS:
Precise levelling route revised
" newly laid
Secondary levelling route revised
Precise levelling route not revised
Sagamino base line
Primary point re-occupied
mentary point re-occupied
" not re occupied but re-adjusted
" " and not re-adjusted
dary triangulation point
ry "
oints re-occupied
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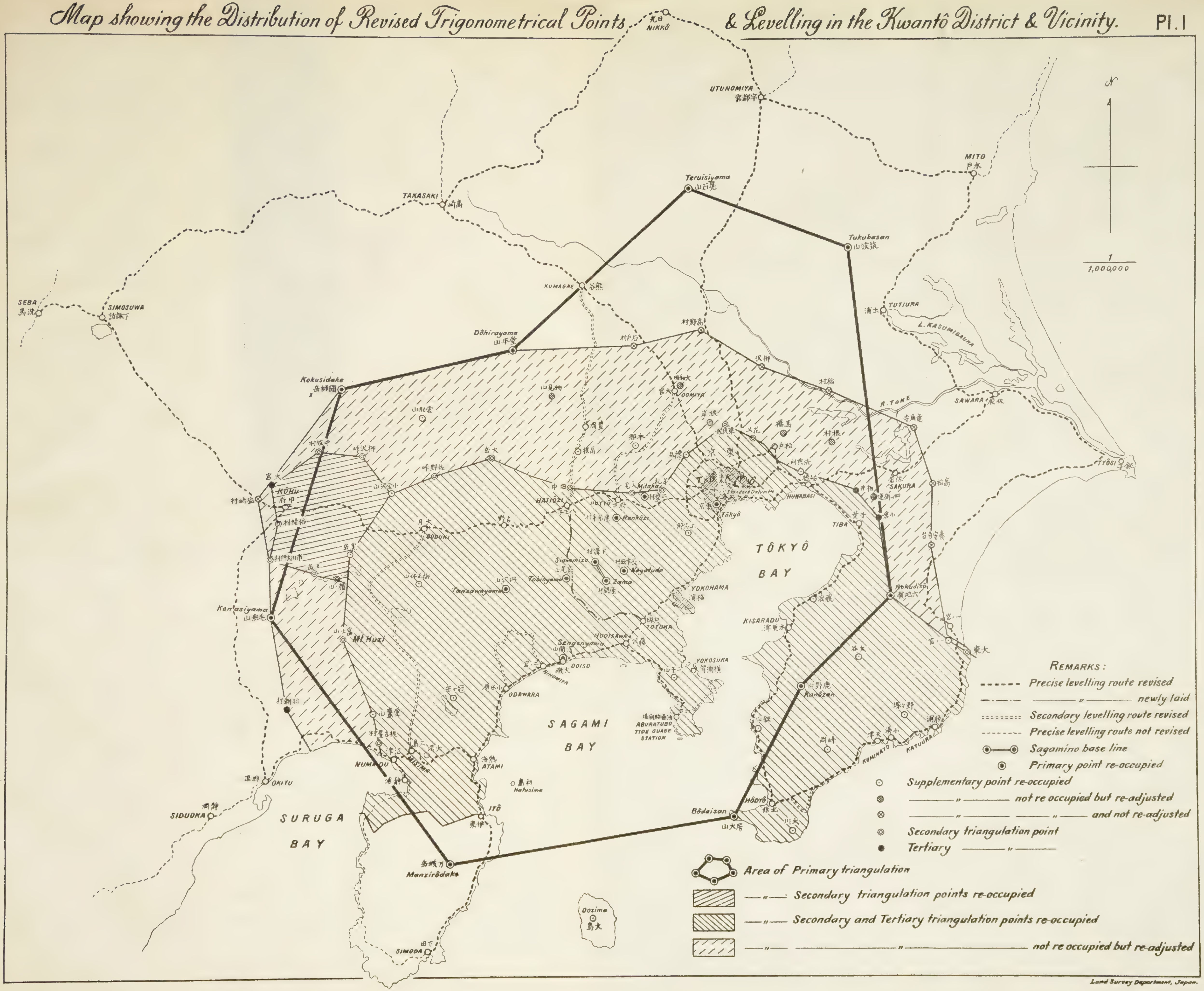
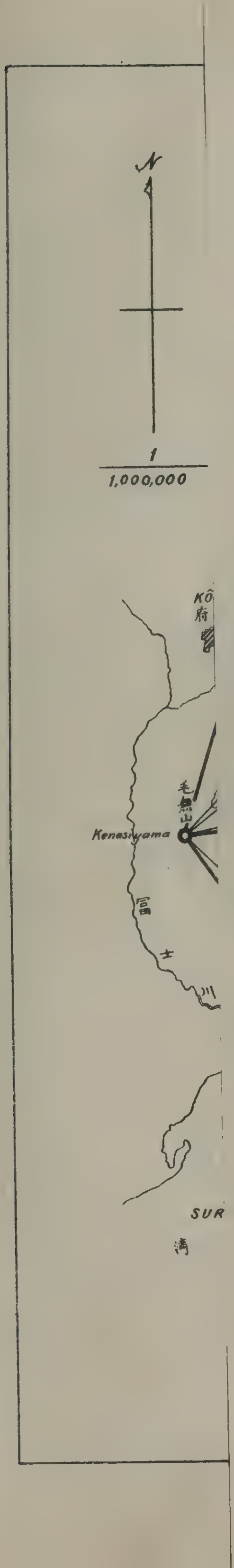
not re occupied but re-adjusted

Land Survey Department, Japan.

Map showing the Distribution of Revised Trigonometrical Points & Levelling in the Kwantô District & Vicinity. Pl. I



Land Survey Department, Japan.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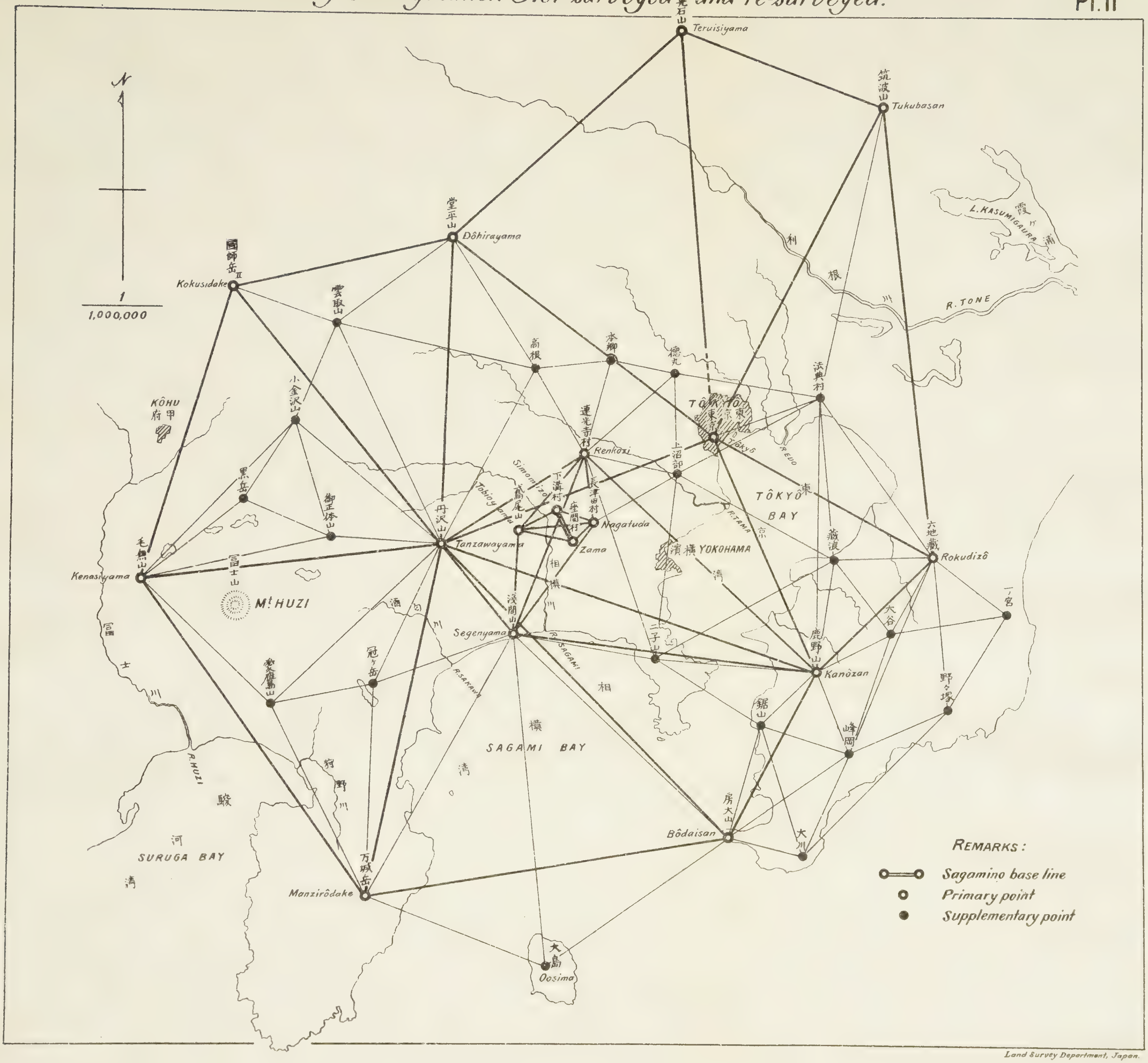
Primary Triangulation Net surveyed and re-surveyed.

Pl. II



Land Survey Department, Japan.

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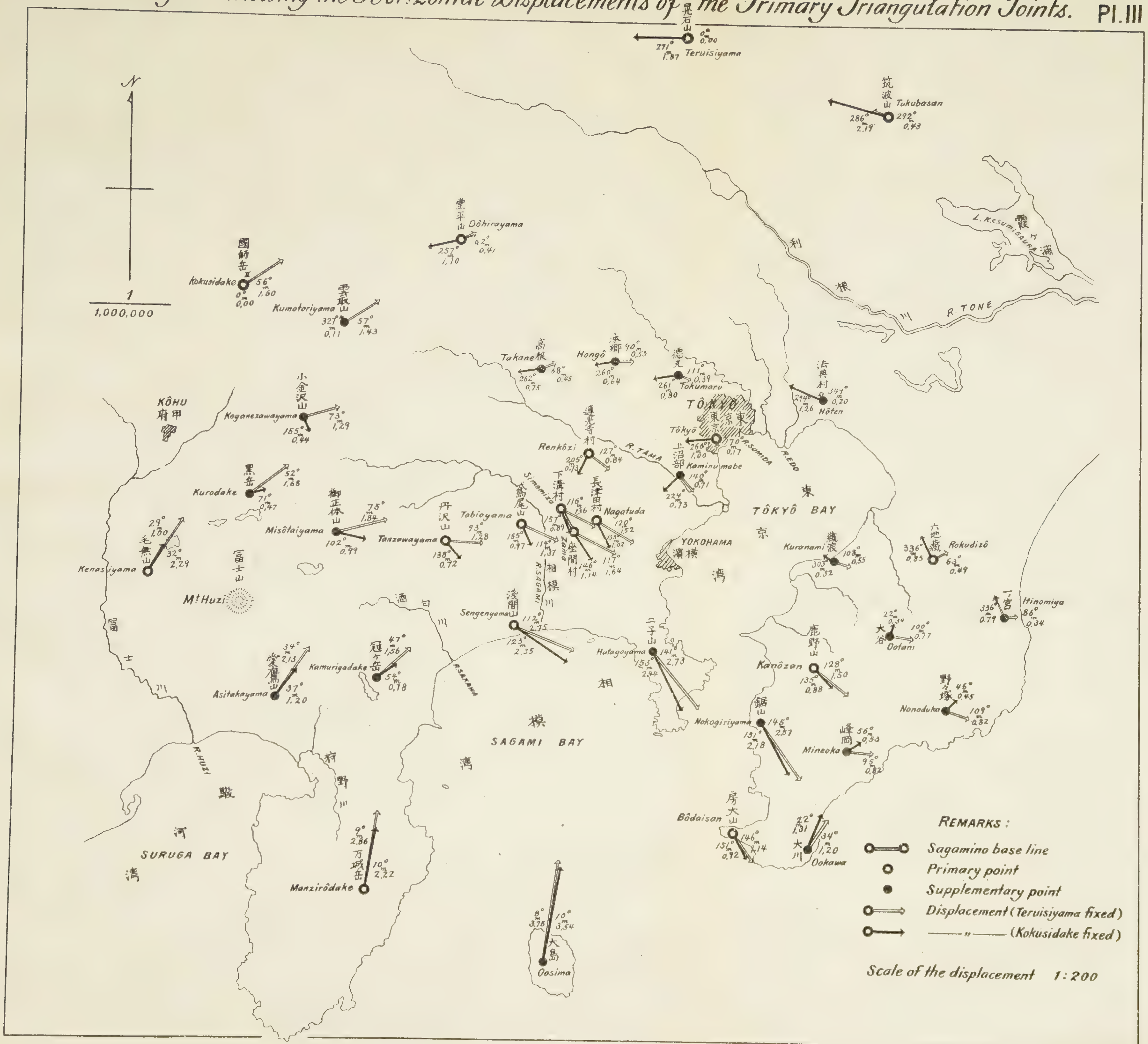
Diagram showing the Horizontal Displacements of the Primary Triangulation Points. Pl. III


N
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晃石山 Teruisiyama 271° 1.87 0° 0.00
筑波山 Tukubasan 286° 2.19 292° 0.43
L. KASUMIGAURA 霞ヶ浦
利根川 R. TONE
堂平山 Dôhirayama 257° 1.10 92° 0.41
國師岳 Kokusidake 56° 1.60 0° 0.00
雲取山 Kumotoriyama 327° 0.11 57° 1.43
高根 Takane 262° 0.75 68° 0.45
本郷 Hongô 260° 0.64 90° 0.55
徳丸 Tokumaru 261° 0.80 111° 0.39
法典村 Hôten 294° 1.26 347° 0.20
KÔHU 甲府
小金沢山 Koganezawayama 73° 1.29 155° 0.44
TÔKYÔ 東京
Tôkyô 268° 1.00 70° 0.17
R. SUMIDA
R. EDO
蓮光寺村 Renkôzi 205° 0.73 127° 0.84
R. TAMA
上沼部 Kaminumabe 224° 0.73 140° 0.71
黒岳 Kurodake 52° 1.68 71° 0.47
御正体山 Misôtaiyama 75° 1.84 102° 0.99
丹沢山 Tanzawayama 93° 1.28 138° 0.72
Tobioyama
鳶尾山 155° 0.97
Simomizo 下溝村 116° 1.36 157° 0.89
長津田村 Nagatuda 120° 1.52 133° 1.02
座間村 Zama 111° 1.37 146° 1.14
117° 1.64
R. SAGAMI 相模川
YOKOHAMA 濱横
東京湾 TÔKYÔ BAY
毛無山 Kenasiyama 29° 1.00 32° 2.29
富士山 Mt Huzi
織浪 Kuranami 303° 0.32 108° 0.55
六地蔵 Rokudizô 336° 0.85 64° 0.49
一宮 Itinomiya 336° 0.79 86° 0.34
大谷 Ootani 22° 0.34 100° 0.77
淺間山 Sengenyama 112° 2.75 125° 2.35
酒匂川 R. SAKAWA
二子山 Hutagoyama 141° 2.73 153° 2.44
鹿野山 Kanôzan 128° 1.50 135° 0.88
野々塚 Nonoduka 46° 0.45 109° 0.82
愛鷹山 Asitakayama 34° 2.13 37° 1.20
冠ヶ岳 Kamurigadake 47° 1.56 54° 0.78
富士川 R. HUZI
相模湾 SAGAMI BAY
鋸山 Nokogiriyama 145° 2.57 131° 2.18
峰岡 Mineoka 56° 0.53 95° 0.82
狩野川
駿河湾 SURUGA BAY
万成岳 Manzirôdake 9° 2.86 10° 2.22
房大山 Bôdaisan 146° 1.14 151° 0.92
大川 Ookawa 22° 1.31 34° 1.20
大島 Oosima 8° 3.78 10° 3.54
REMARKS:
Sagamino base line
Primary point
Supplementary point
Displacement (Teruisiyama fixed)
——"—— (Kokusidake fixed)
Scale of the displacement 1:200

Land Survey Department, Japan.

osing Errors.

Pl. IV

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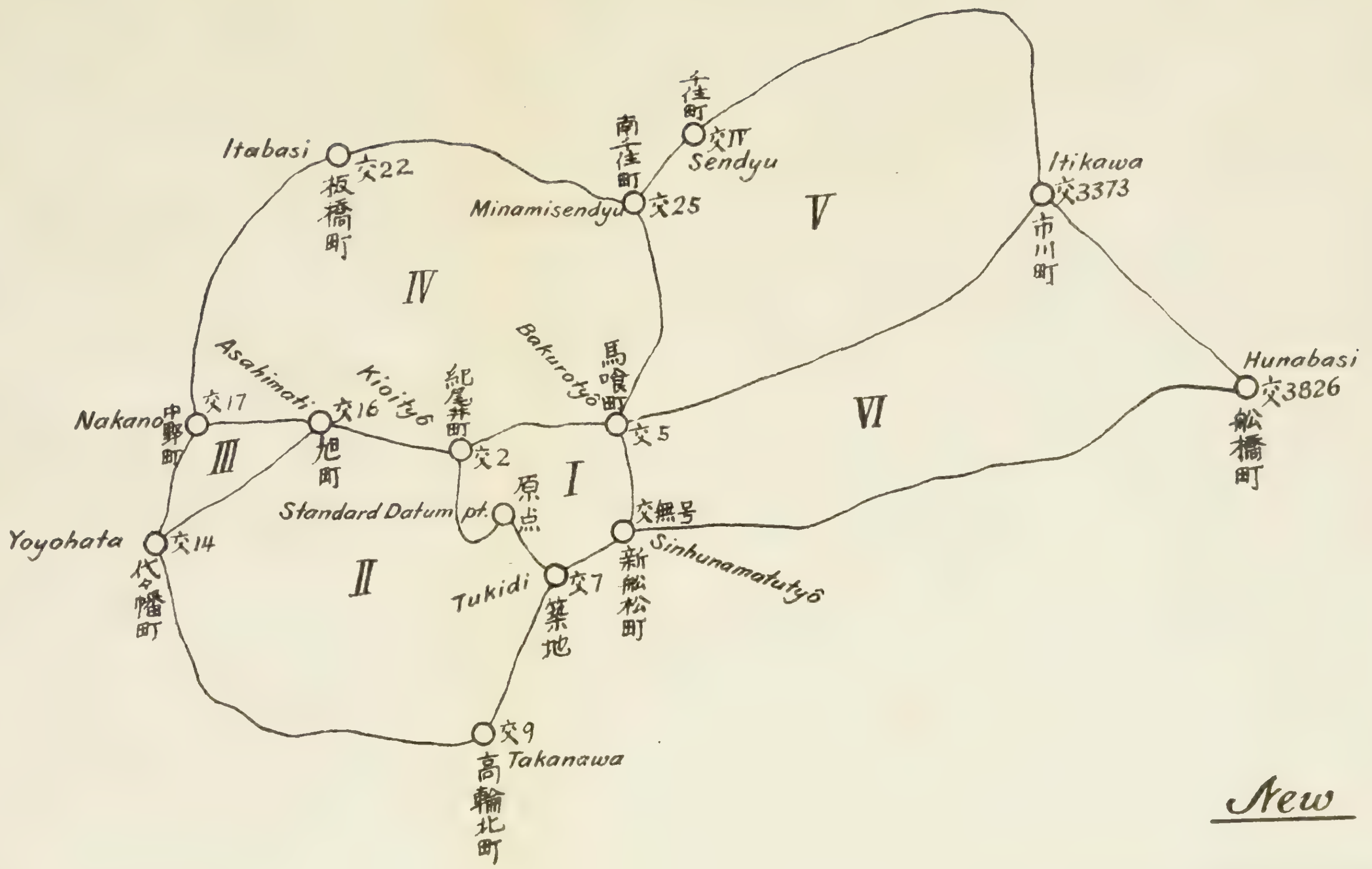
v

	rror	length of circuit
No	^{m},4	18^{km},7
	,9	32,2
	,8	11,5
	,3	37,0
	,7	38,4
	,3	56,9

= ± 0^{mm},80

Land Survey Department, Japan.

Precise-levelling Net in Tôkyô and Vicinity with Comparison of Closing Errors.



Old

No of circuit	closing error	length of circuit
I	$-\ 2\overset{mm}{.}1$	$17\overset{km}{.}3$
II	+ 10.1	30.1
III	+ 4.1	12.1
IV	− 3.3	36.5
V	− 1.3	37.2

$$M = \sqrt{\frac{[\Delta K]}{v}} = \pm 1\overset{mm}{.}1$$

New

No of circuit	closing error	length of circuit
I	$+\ 3\overset{mm}{.}4$	$18\overset{km}{.}7$
II	− 3.9	32.2
III	− 1.8	11.5
IV	+ 2.3	37.0
V	+ 5.7	38.4
VI	+ 5.3	56.9

$$M = \sqrt{\frac{[\Delta K]}{v}} = \pm 0\overset{mm}{.}80$$

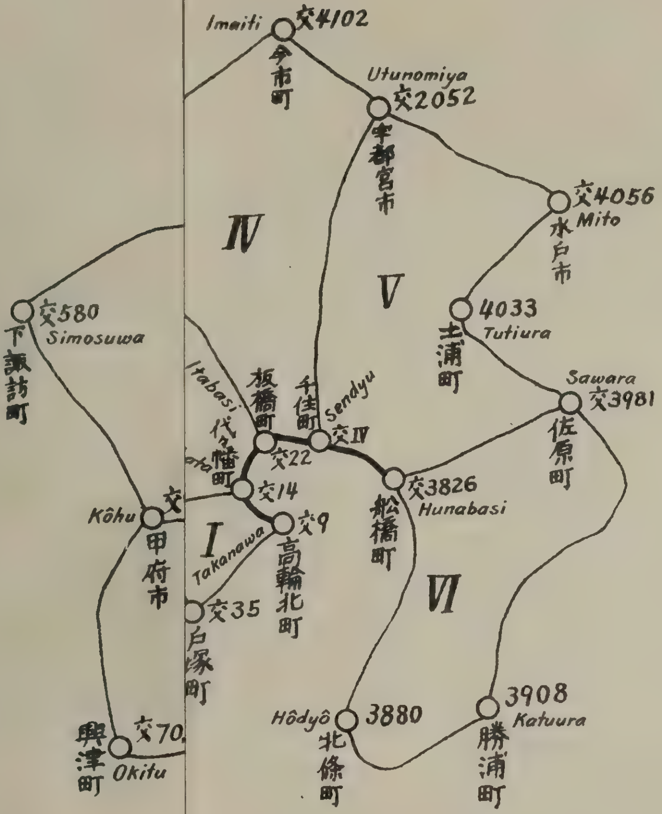
M : mean error per one kilometre derived from net adjustment.

Land Survey Department, Japan.

losing Errors.

Pl. V

ew



rror	length of circuit
mm	Km
,2	117,8
,5	376,7
,8	421,8
,8	330,7
,7	322,0
,5	379,8

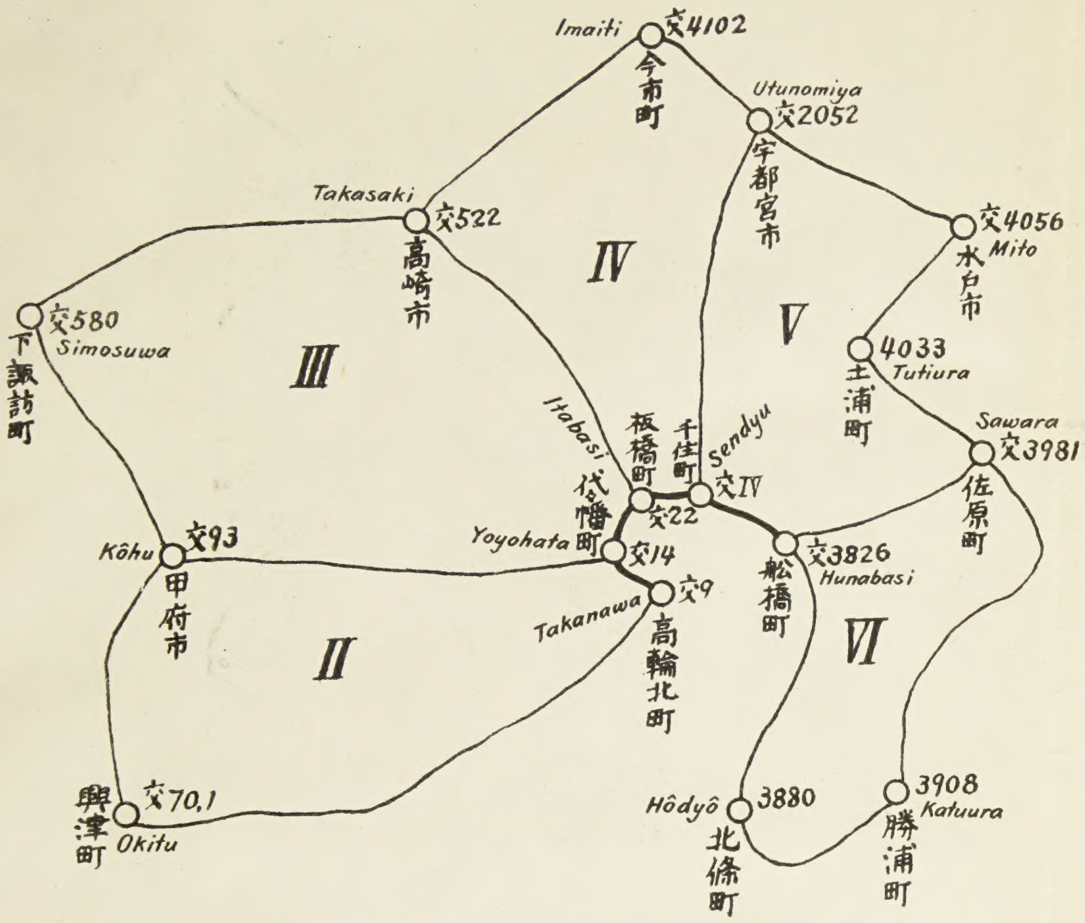
$= \pm 1\overset{mm}{,}62$

Land Survey Department, Japan.

Precise-levelling Net in the Kwantô District with Comparison of Closing Errors.

Pl. V

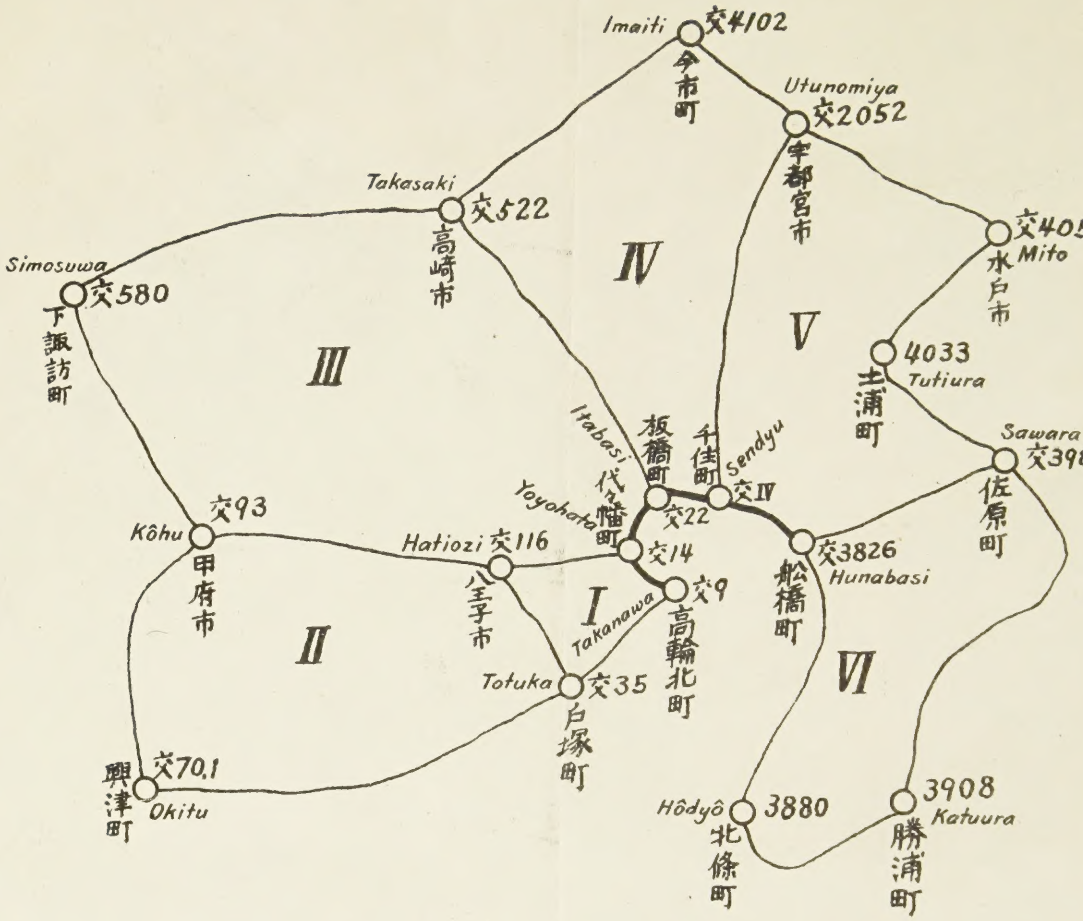
Old



No of circuit	closing error	length of circuit
II	$-66\overset{\mathrm{mm}}{,}0$	$396\overset{\mathrm{Km}}{,}7$
III	− 45,8	422,3
IV	+ 45,0	331.7
V	− 27,2	332,0
VI	+ 13,1	379,6

$$M = \sqrt{\frac{[\Delta K]}{v}} = \pm 2\overset{\mathrm{mm}}{,}30$$

New



No of circuit	closing error	length of circuit
I	$+7\overset{\mathrm{mm}}{,}2$	$117\overset{\mathrm{Km}}{,}8$
II	+ 9,5	376,7
III	+ 64,8	421,8
IV	− 0,8	330,7
V	− 18,7	322,0
VI	+ 10,5	379,8

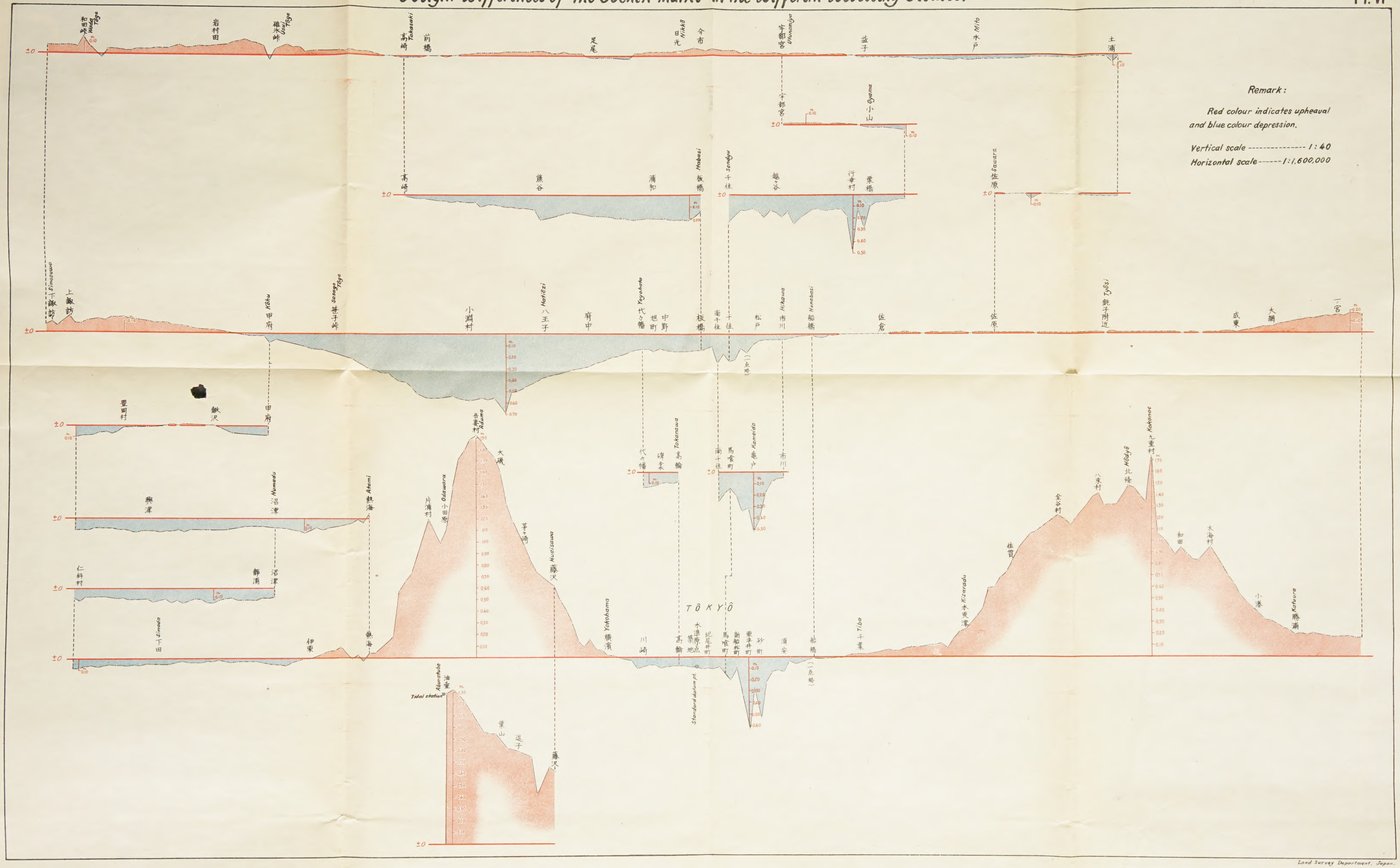
$$M = \sqrt{\frac{[\Delta K]}{v}} = \pm 1\overset{\mathrm{mm}}{,}62$$

M : mean error per one kilometre derived from net adjustment.

Land Survey Department, Japan.

Height Differences of the Bench-marks in the Different Levelling Routes.

Pl. VI



Remark:

Red colour indicates upheaval and blue colour depression.

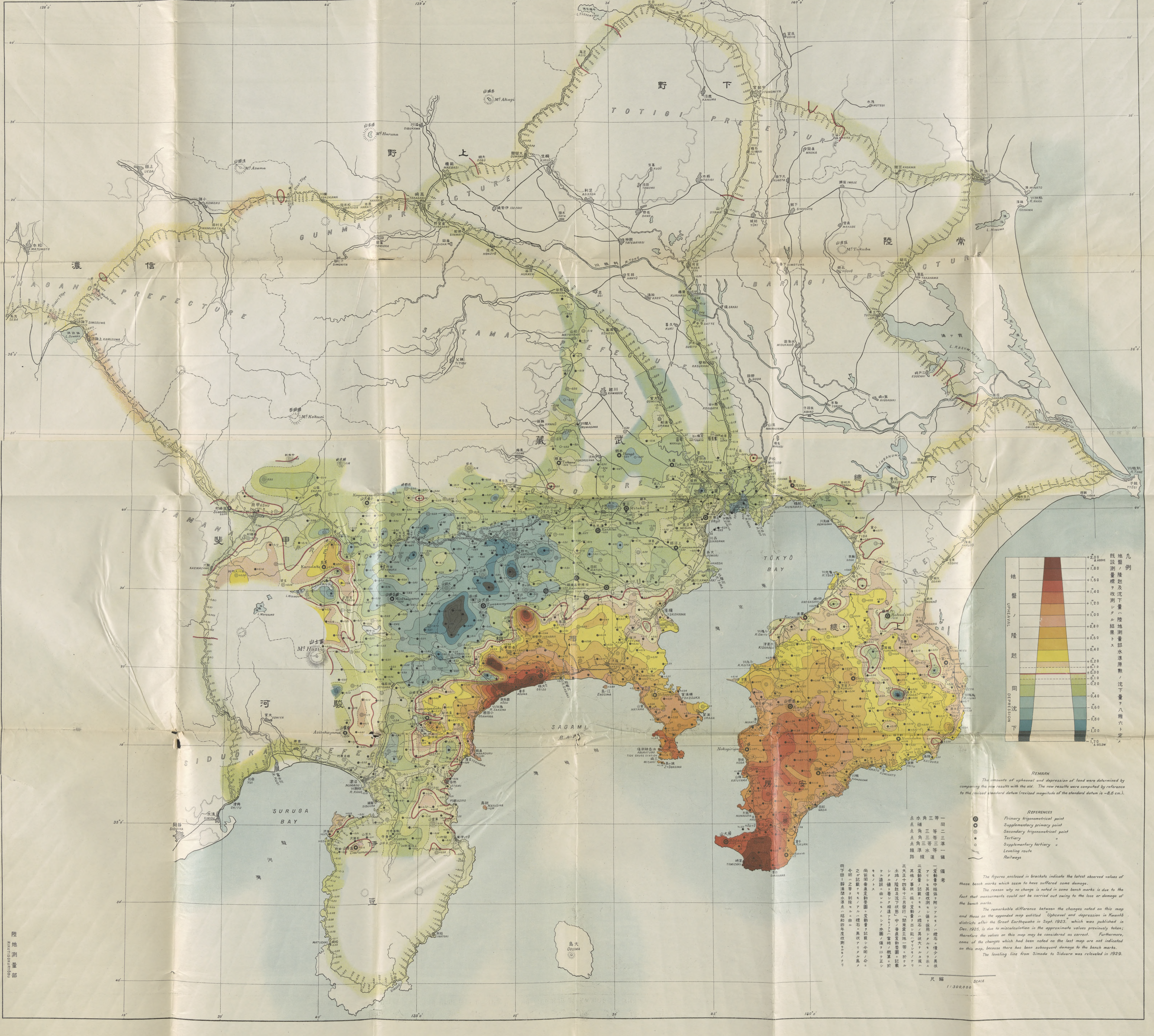
Vertical scale -------------- 1:40
Horizontal scale ------ 1:1,600,000

Land Survey Department, Japan.

大正十二秊關東震災地垂直變動要圖

Map showing the Depression and Upheaval of the Ground produced at Kwantô Districts after the Great Earthquake of Sept. 1st. 1923.

Pl. VII



凡例

地盤ノ隆起及沈下量ハ陸地測量部水準原點ノ沈下量ヲ八糎六ト定メ既設測量標ヲ改測シタル結果トス

REMARK

The amounts of upheaval and depression of land were determined by comparing the new results with the old. The new results were computed by reference to the revised standard datum (revised magnitude of the standard datum is −8,6 cm.).

REFERENCES

一等三角本点	◉	Primary trigonometrical point
同補点	●	Supplementary primary point
二等三角点	◎	Secondary trigonometrical point
三等三角点	•	Tertiary 〃
準三等三角点	○	Supplementary tertiary 〃
一等水準線	⚬–⚬	Leveling route
鐵道線路	〜	Railways

備考

一、変動量中括弧ヲ附シアルモノハ標石ニ僅少ノ異状アリシモ其儘改測セシ値ヲ採用シタルモノヲ示ス

二、変動量ノ記載ナキモノハ標石ノ異状大ナルカ或ハ其他ノ事故ニ依リ変動量ヲ出シ能ハザリシモノナリ

三、大正十四年十二月發行「関東震災地一帶ニ於ケル土地ノ隆起及沈下状態」中ノ垂直変動要圖ニ記載シタル値ト著シク相違アルモノアルハ當時ノ概算ニ於ケル過誤ニ由レルモノニシテ本圖ノ値ヲ以テ正シキモノトス

尚前回垂直変動要圖ニ変動量ヲ記載シ今回ノ分ニ之ガ記載ナキモノアルハ標石ニ異状アリタル爲メ今回ハ之等ヲ削除セルニ由ル

四、下田—靜浦間水準点ハ昭和四年度改測セルモノナリ

The figures enclosed in brackets indicate the latest observed values of those bench marks which seem to have suffered some damage.

The reason why no change is noted in some bench marks is due to the fact that measurments could not be carried out owing to the loss or damage of the bench marks.

The remarkable difference between the changes noted on this map and those on the appended map entitled "Upheaval and depression in Kwantô districts after the Great Earthquake in Sept. 1923." which was published in Dec. 1925, is due to miscalculation in the approximate values previously taken; therefore the values on this map may be considered as correct. Furthermore, some of the changes which had been noted on the last map are not indicated on this map, because there has been subsequent damage to the bench marks.

The leveling line from Simoda to Siduura was releveled in 1929.

縮尺 SCALE

1:300,000

陸地測量部
RIKUTISOKURYÔBU